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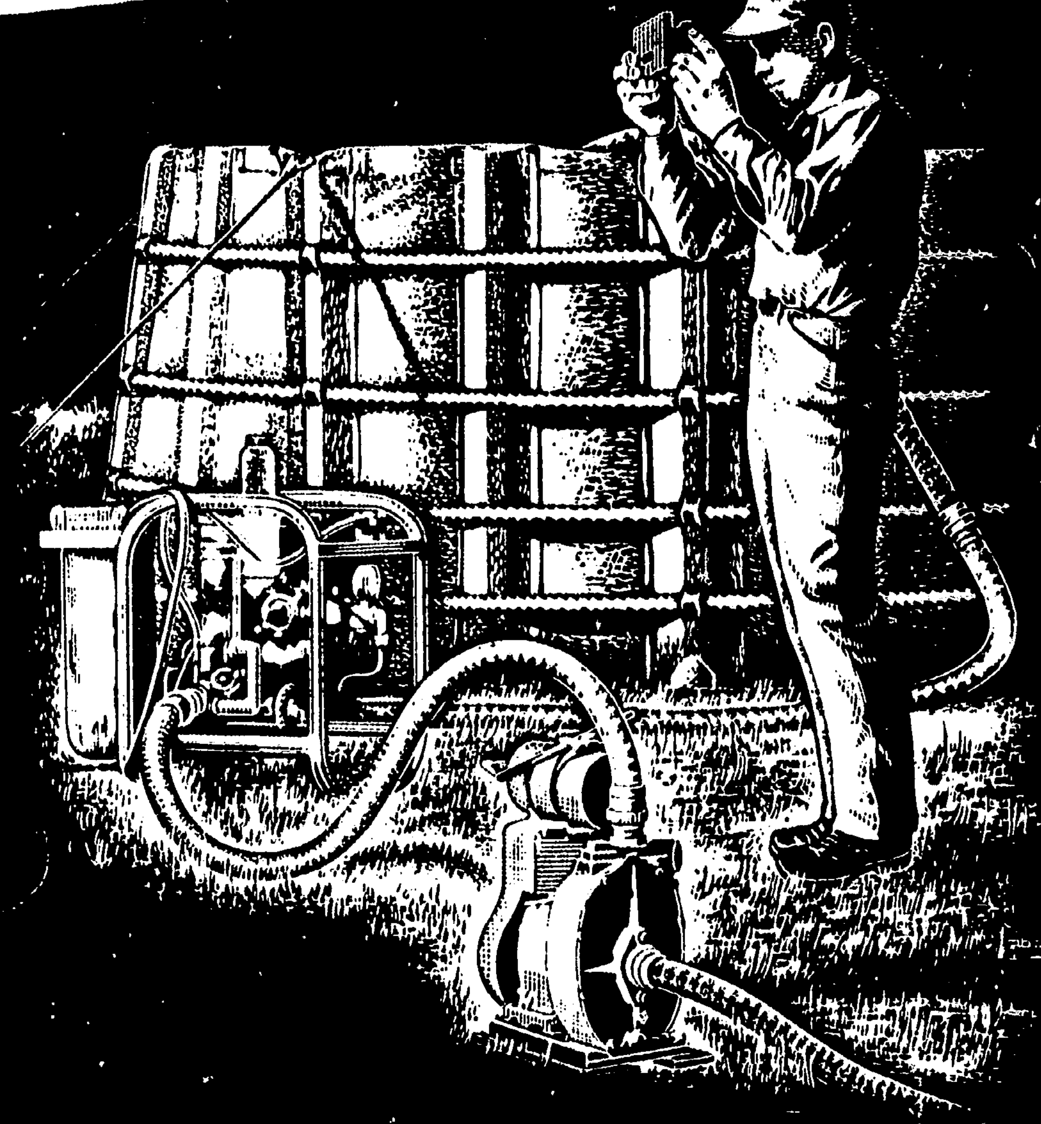
ABSTRACT

This Rate Training Manual provides the technical knowledge and skill requirements necessary to prepare Utilitiesmen to perform tasks involved in the installation, maintenance, and repair of plumbing, heating, steam, fuel storage and distribution systems, water treatment and distribution systems, air conditioning and refrigeration equipment, and sewage collecting and disposal facilities. (Author)



UTILITIESMAN 3 & 2

NAVAL TRAINING COMMAND

RATE TRAINING MANUAL NAVTRA 10656-F

PREFACE

The primary purpose of training is to produce a combat Navy which can ensure victory at sea. A victorious Navy is dependent upon the superior readiness of personnel. A superior quality of training will ensure superior readiness.

This Rate Training Manual provides the technical knowledge and skill requirements necessary to prepare Utilitiesmen to perform tasks involved in the installation, maintenance, and repair of plumbing, heating, steam, fuel storage and distribution systems, water treatment and distribution systems, air conditioning and refrigeration equipment, and sewage collecting and disposal facilities.

This training manual was prepared by the Naval Training Publications Detachment, Washington, D. C., for the Chief of Naval Training. Technical assistance was provided by the Naval Facilities Engineering Command; the Naval Examining Center; the Naval Schools Construction, Port Hueneme, California; the Naval Schools Construction, Davisville, Rhode Island; and the Naval Construction Training Unit, Gulfport, Mississippi.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CHAPTER 1

MEET THE UTILITIESMAN

This training manual has been prepared for men of the Navy and of the Naval Reserve who are studying for advancement to the rates of Utilitiesman 3 and Utilitiesman 2. The occupational, professional, or technical quals for the Utilitiesman rating that were used as a guide in the preparation of this training manual are current through change 1 (1972) to the Manual of Qualifications for Advancement, NavPers 18068-C.

This chapter gives information on the enlisted rating structure, the Utilitiesman rating, requirements and procedures for advancement, and references that will help you both in working for advancement and in performing your duties as a Utilitiesman. Information on how to make the best use of this training manual also is included. It is strongly recommended that you study this chapter carefully before beginning intensive study of the remainder of this training manual.

THE ENLISTED RATING STRUCTURE

The two main types of ratings in the present enlisted rating structure are general ratings and service ratings.

GENERAL RATINGS identify broad occupational fields of related duties and functions. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

An example of the General Rating is the Utilitiesman (UT) rating, which is a straight progression from Construction Recruit (CR) to Master Chief Utilitiesman (UTCM):

Equipment Operator
CR-CA-CN-UT3-UT2-UT1-UTC-UTCS-UTCM

SERVICE RATINGS identify subdivisions or specialties within a general rating. Although service ratings can exist at any petty officer level, they are most common at the PO3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

The Electronics Technician (ET) is an example of a general rating which has two service ratings within its structure from Seaman Apprentice (SA) to Electronics Technician First Class (ET1). This provides for specialization in training and utilization of personnel.

This general rating career pattern is as follows:

Electronics Technician

SA-SN-ETN3-ETN2
SR ET1-ETC-ETCS-ETCM
SA-SN-ETR3-ETR2

THE UTILITIESMAN RATING

The Utilitiesman rating is now a general rating as are all others in the Group VIII ratings. Utilitiesmen plan, supervise, and perform tasks involved in the installation, maintenance and repair of plumbing, heating, steam, fuel and water distribution and treatment systems, air-conditioning and refrigeration equipment, and sewage disposal facilities, as prescribed by drawings and specifications. They prepare records and reports. In addition, Utilitiesmen schedule and evaluate installation and operational tasks.

NECs

The Utilitiesmen rating is a source of a number of Navy Enlisted Classification Codes (NECs). NECs reflect special knowledge and skills not indicated by a man's rate alone. They are management tools for the proper utilization of manpower. NECs available to Utilitiesmen at certain grade levels are described in chapter 2 of this training manual.

TYPES OF BILLETS

The majority of Utilitiesmen are serving in mobile construction battalions engaged in overseas construction. An amphibious construction battalion has a limited number of Utilitiesmen assigned to it. If you are assigned to an amphibious construction battalion, it will be at Little Creek, Virginia, on the East Coast, or at Coronado, California, on the West Coast. Some Utilitiesmen also are assigned to CBMUs (Construction Battalion Maintenance Units). Members of CMBUs are concerned with maintenance of advanced bases.

Outside the battalions, a limited number of Utilitiesmen are assigned to a variety of billets in the Public Works Departments of naval shore activities. In addition, especially well qualified Utilitiesmen are assigned instructor duty at the Utilitiesman school at Port Hueneme, California, and at the Utilitiesman school at Davisville, Rhode Island.

Geographical Location

The Navy maintains a large number of activities within the United States, mostly along the coastline. As a Utilitiesman, you may work at most any one of them, either as a member of a unit of the Fleet operating at the station, or as a member of the station force itself.

In the Atlantic area you may be assigned duty in Turkey, Spain, Italy, Ireland, Newfoundland, or even Iceland or Greenland. You may also work in Bermuda or at a number of other islands—Cuba, Trinidad, Antigua, Turks Island, etc. You may have the opportunity to winter over in Antarctica.

In the Pacific area you may be assigned duty in Okinawa, Japan, Alaska, Guam, Saipan, or the Philippines. You may even work in Thailand, Cambodia, Viet Nam, or Indonesia.

Units of the Fleet

As a Utilitiesman, you most likely will be assigned to a mobile construction battalion, or a detachment thereof, or to other activities related to the Fleet Construction Force, such as a Construction Battalion Base Unit (CBBU), regimental headquarters, or Construction Force headquarters. In a mobile construction battalion, you may expect to be in the Utilities Platoon of B Company. B Company is a special construction company, and militarily is a rifle company. You may also be assigned to a Cargo Handling Battalion, which is staffed principally by Supply Corps officers and enlisted personnel of other than SEABEE ratings.

Duty at Overseas Bases

In general, you may expect to work in your rate if assigned to a shore activity outside the United States. As a rule, you will work with foreign nationals, or civil service workers. As you advance in rate, you may be afforded the opportunity to serve as a member of a SEABEE Team. Only men of the highest caliber are chosen for duty as SEABEE Team members.

A SEABEE Team normally consists of 12 men with an officer in charge of the team. Members of a SEABEE Team undergo about 16 weeks of rigorous training. During this period, members learn to speak the foreign language of the country to which they are going to deploy. Also, a team member learns about another rating; for example, a SW in a team may spend two weeks at the UT school learning the fundamentals of plumbing or boilers.

After their training is complete, SEABEE Teams are deployed to a foreign country to assist the people of that country. Some of the ways the SEABEE Teams assist a country is to show personnel of an area or village how to dig a water well, how to construct wooden bridges, and in general how to improve their living conditions. SEABEE Teams endeavor to win the friendship and admiration of the countries they serve in. There could be many more meritorious things said about the SEABEE Teams, but in this book space does not permit. For further information on the duties of a SEABEE Team member, see your first class or chief.

PRACTICAL LEADERSHIP ASPECTS

Your status as a Constructionman might be roughly described as that of a relatively unskilled construction worker with little or no responsibility for the training and supervision of subordinates. Your status as a Utilitiesman Third will be that of a more highly skilled construction worker with a larger responsibility for the training and supervision of subordinates.

In short, when you become a petty officer you become a link in the chain of command which extends from the battalion CO down through the various officer grades and petty officer rates to the nonrated men in the battalion. Your responsibilities are more than just giving orders and seeing that work is done. You also have a responsibility for sharing your knowledge with others. When you become a petty officer, the Navy expects you to do your part in the training of the men under you. For success in training and supervising others, it is important that you be an effective leader.

General Order No. 21 states that successful leadership at all levels is based on personal example and moral responsibility. As you prepare for advancement to UT3 and then to UT2, your responsibilities in connection with General Order 21 and the naval leadership program will increase, as will the application of leadership to the duties of your rating.

A discussion on leadership is presented in Military Requirements for Petty Officer 3 & 2, NavPers 10056. Read the material on leadership in NavPers 10056 and try to think of ways in which you can apply the information it contains to your technical duties as a Utilitiesman Third or Second.

On the technical side, the Utilitiesman petty officer must possess the leadership qualities required to train and supervise a crew of subordinates who are capable of production under his supervision, construction of the first quality, performed in accordance with drawings and specifications (where applicable), and completed on or ahead of schedule. As a Utilitiesman Third your crews will be small; they will increase in size as you rise through the rates and show yourself capable of assuming greater responsibility.

As is the case with practically any type of technical leadership, an essential requirement is the possession of a vast amount of technical knowledge and technical skill. Along with this must go the capacity for extending this knowledge and skill to subordinates, plus the ability to organize both the job and the men in the manner which will best expedite the work and develop each man's particular knowledge and skill.

An indispensable part of leadership is the confidence and respect of your subordinates. To gain the confidence and respect of your men, it is important, among other things, that you show an interest in others; know your job; be friendly and courteous; and give praise and compliments where deserved.

ADVANCEMENT

Some of the rewards of advancement are easy to see. You get more pay. Your job assignments become more interesting and more challenging. You are regarded with greater respect by officers and enlisted personnel. You enjoy the satisfaction of getting ahead in your chosen Navy career.

But the advantages of advancement are not yours alone. The Navy also profits. Highly trained personnel are essential to the functioning of the Navy. By each advancement, you increase your value to the Navy in two ways. First, you become more valuable as a specialist in your own rating, and second, you become more valuable as a person who can train others and thus make far-reaching contributions to the entire Navy.

HOW TO QUALIFY FOR ADVANCEMENT

What must you do to qualify for advancement? The requirements may change from time to time, but usually you must:

1. Have a certain amount of time in your present grade.
2. Complete the required military and rating manuals.
3. Demonstrate your ability to perform all the PRACTICAL requirements applicable to the rate for which you are seeking advancement and have them checked off on the Record of Practical Factors, NavPers 1414/1.
4. Be recommended by your commanding officer, after the petty officers supervising your work have indicated that they considered you capable of performing the duties of the next higher rate.
5. Demonstrate your KNOWLEDGE by passing written examinations on the occupational and military qualification standards for advancement.

Some of these general requirements may be modified in certain ways. Figure 1-1 gives a more detailed view of the requirements for advancement of active duty personnel; figure 1-2 gives this information for inactive duty personnel.

Remember that the qualifications for advancement can change. Check with your division officer or training officer to be sure that you know the most recent qualifications.

REQUIREMENTS *	E1 to E2	E2 to E3	#† E3 to E4	#E4 to E5	† E5 to E6	† E6 to E7	† E7 to E8	† E8 to E9
SERVICE	4 mos. service—or completion of Recruit Training.	8 mos. as E-2.	6 mos. as E-3	12 mos. as E-4	24 mos. as E-5.	36 mos. as E-6. 8 years total enlisted service.	36 mos. as E-7. 8 of 11 years total service must be enlisted.	24 mos. as E-8. 10 of 13 years total service must be enlisted.
SCHOOL	Recruit Training. (C.O. may advance up to 10% of graduating class.)		Class A for PR3, DT3, PT3, AME 3, HM 3, PN 3, FTB 3, MT 3.			Class B for AGC MUC, MNC. ††		
PRACTICAL FACTORS	Locally prepared check-offs.	Record of Practical Factors, NavPers 1414/1, must be completed for E-3 and all PO advancements.						
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.					
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.					
EXAMINATIONS**	Locally prepared tests.	See below.	Navy-wide examinations required for all PO advancements.				Navy-wide, selection board.	
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)		Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NavPers 10052 (current edition).					Correspondence courses and recommended reading. See NavPers 10052 (current edition).	
AUTHORIZATION	Commanding Officer		Naval Examining Center					

* All advancements require commanding officer's recommendation.
† 1 year obligated service required for E-5, and E-6; 2 years for E-7, E-8, and E-9.
\# Military leadership exam required for E-4 and E-5. †† Waived for qualified EOD personnel.
** For E-2 to E-3, NAVEXAMCEN exams or locally prepared tests may be used.

Figure 1-1.—Active duty advancement requirements.

REQUIREMENTS *	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
TOTAL TIME IN GRADE	4 mos.	8 mos.	6 mos.	12 mos.	24 mos.	36 mos. with total 8 yrs service	36 mos. with total 11 yrs service	24 mos. with total 13 yrs service
TOTAL TRAINING DUTY IN GRADE †	14 days	14 days	14 days	14 days	28 days	42 days	42 days	28 days
PERFORMANCE TESTS			Specified ratings must complete applicable performance tests before taking examination.					
DRILL PARTICIPATION	Satisfactory participation as a member of a drill unit in accordance with BUPERSINST 5400.42 series.							
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)	Record of Practical Factors, NavPers 1414/1, must be completed for all advancements.							
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	Completion of applicable course or courses must be entered in service record.							
EXAMINATION	Standard Exam		Standard Exam required for all PO advancements. Also pass Military Leadership Exam for E-4 and E-5.				Standard Exam, Selection Board.	
AUTHORIZATION	Commanding Officer		Naval Examining Center					

*Recommendation by commanding officer required for all advancements.
† Active duty periods may be substituted for training duty.

Figure 1-2.—Inactive duty advancement requirements.

Advancement is not automatic. Even though you have met all the requirements, including passing the written examinations, you may not be able to "sew on the crow" or "add a stripe." The number of men in each rate and rating is controlled on a Navywide basis. Therefore, the number of men who may be advanced is limited by the number of vacancies that exist. When the number of men passing the examination exceeds the number of vacancies, some system must be used to determine which men may be advanced and which may not. The system used is the "final multiple" and is a combination of three types of advancement systems.

Merit rating system
Personnel testing system
Longevity, or seniority, system

The Navy's system provides credit for performance, knowledge, and seniority, and, while it cannot guarantee that any one person will be advanced, it does guarantee that all men within a particular rating will have equal advancement opportunity.

The following factors are considered in computing the final multiple:

POINTS	FACTOR	WEIGHT
80 (MAX)	Examination Score	40%
50 (MAX)	Performance (Average of marks received	25%
20 (MAX)	Total Active Service (1 per yr)	10%
20 (MAX)	Time in Present Grade (2 per yr)	10%
15 (MAX)	Medals and Awards	7.5%
15 (MAX)	PNA (Maximum 3 per exam cycle)	7.5%
200 (MAX POSSIBLE)		100%

All of the above information (except the examination score and the PNA factor) is submitted to the Naval Examining Center with your examination answer sheet. After grading, the examination scores, for those passing, and the PNA points (additional points awarded to those who previously passed the examination but were not advanced) are added to the other factors to arrive at the final multiple. A precedence list, which is based on final multiples, is then prepared for each pay grade within each rating. Advancement authorizations are then issued, beginning at the top of the list, for the number of men needed to fill the existing vacancies.

PNA FACTOR

PNA points are comprised of two subfactors, Navy-wide examination score and performance mark standing. Individually, both subfactors are weighted in relation to a member's standing among all those who participated in his specific examination rate for a given cycle. In the case of the performance mark standing subfactor, individual performance mark averages submitted to the Naval Examining Center are used as the basis for determining the member's performance standing in relation to his contemporaries. For those who pass examinations but are not advanced, additional points will be credited to their final multiple for succeeding examinations in accordance with the schedule established for each subfactor as follows:

EXAMINATION SCORE	POINTS
70 through 80	1.5
60 through 69	1.0
Passing through 59	.5

PERFORMANCE MARK AVERAGE	POINTS
Top 25 Percent	1.5
Upper 25 to 50 Percent	1.0
Lower 50 to 25 Percent	.5
Bottom 25 Percent	.0

NOTE: Maximum of 3 multiple points per cycle. Maximum of 15 multiple points after 5 exam cycles.

PNA points will be awarded as follows: A maximum of three points can be accrued each examination cycle. After five examination cycles, candidates will be eligible for the maximum number of points (15). Subsequent to complete implementation, each candidate's PNA factor will be computed based on the points received in the five most recent examinations competed in, out of the last six examinations. This will allow candidates to miss one examination and still be eligible for the maximum award.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement? You must study the qualifications for advancement, work on the practical factors, study the required rate training manuals, and study other material that is required for advancement in your rating. To prepare for advancement, you will need to be familiar with (1) the Quals Manual, (2) the Record of Practical Factors, (3) a NavPers publication called Bibliography for Advancement Study, NAVTRA 10052, and (4) applicable rate training manuals. The following sections describe them and give you some practical suggestions on how to use them in preparing for advancement.

Quals Manual

The Manual of Qualifications for Advancement, NavPers 18068-C (with changes), gives the minimum occupational and military qualification standards for advancement to each pay grade within each rating. This manual is usually called the Quals Manual, and the qualifications themselves are often called "quals." The qualification standards are of two general types: (1) military qualification standards and (2) occupational qualification standards.

MILITARY STANDARDS are requirements that apply to all ratings rather than to any one particular rating. Military requirements for advancement to third class and second class petty officer rates deal with military conduct, naval organization, military justice, security, watch standing, and other subjects which are required of petty officers in all ratings.

OCCUPATIONAL STANDARDS are requirements that are directly related to the work of each rating.

Both the military requirements and the occupational qualification standards are divided into subject matter groups; then, within each subject matter group, they are divided into PRACTICAL FACTORS and KNOWLEDGE FACTORS. Practical factors are things you must be able to DO. Knowledge factors are things you must KNOW in order to perform the duties of your rating.

In most subject matter areas, you will find both practical factor and knowledge factor qualifications. In some subject matter areas, you may find only one or the other. It is important to remember that there are some knowledge aspects to all practical factors, and some practical aspects to most knowledge factors. Therefore, even if the Quals Manual indicates that there are no knowledge factors for a given subject matter area, you may still expect to find examination questions dealing with the knowledge aspects of the practical factors listed in that subject matter area.

You are required to pass a Navywide military/leadership examination for E-4 or E-5, as appropriate, before you take the occupational examinations. The military/leadership examinations are administered on a schedule determined by your commanding officer. Candidates are required to pass the applicable military/leadership examination only once. Each of these examinations consists of 100 questions based on information contained in Military Requirements for Petty Officer 3 & 2, NavPers 10056, and other publications listed in the Bibliography for Advancement Study, NAVTRA 10052.

The Navywide occupational examinations for pay grades E-4 and E-5 will contain 150 questions related to occupational areas of your rating.

If you are working for advancement to second class, remember that you may be examined on third class qualifications as well as on second class qualifications.

The Quals Manual is kept current by means of changes. The occupational qualifications for your rating which are covered in this training manual were current at the time the manual was printed. By the time you study this manual, however, the quals for your rating may have been changed. Never trust any set of quals until you have checked it against an UP-TO-DATE Quals Manual.

Record of Practical Factors

Before you can take the servicewide examination for advancement, there must be an entry in your service record to show that you have qualified in the practical factors of both the military qualifications and the occupational qualifications. This form is available for each rating. The form lists all practical factors, both military and occupational. As you demonstrate your ability to perform each practical factor, appropriate entries are made in the DATE and INITIALS columns.

Changes are made periodically to the Manual of Qualifications for Advancement, and revised forms of NavPers 1414/1 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement.

Until completed, the NavPers 1414/1 is usually held by your division officer; after completion, it is forwarded to the personnel office for insertion in your service record. If you are transferred before qualifying in all practical factors, the incomplete form should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form actually is inserted in your service record before you are transferred. If the form is not in your service record, you may be required to start all over again and requalify in the practical factors which have already been checked off.

NAVTRA 10052

The Bibliography for Advancement Study, NAVTRA 10052 (revised), is a very important publication for any enlisted person preparing for advancement. This bibliography lists required and recommended rate training manuals and other reference material to be used by personnel working for advancement.

NAVTRA 10052 is revised and issued once each year by the Naval Training Support Command. Each revised edition is identified by a letter following the NAVTRA number. When using this publication, be SURE that you have the most recent edition.

If extensive changes in qualifications occur in any rating between the annual revisions of NAVTRA 10052, a supplementary list of study material may be issued in the form of a NAVTRA Notice. When you are preparing for advancement, check to see whether changes have been made in the qualifications for your rating. If changes have been made, see if a NAVTRA Notice has been issued to supplement NAVTRA 10052 for your rating.

The required and recommended references are listed by pay grade in NAVTRA 10052. If you are working for advancement in third class, study the material that is listed for third class. If you are working for advancement to second class, study the material that is listed for second class; but remember that you are also responsible for the references listed at the third class level.

In using NAVTRA 10052 you will notice that some rate training manuals are marked with an asterisk(*). Any manual marked in this way is MANDATORY—that is, it must be completed at the indicated rate level before you can be eligible to take the servicewide examination for advancement. Each mandatory manual may be completed by (1) passing the appropriate enlisted correspondence course that is based on the mandatory training manual; (2) passing locally prepared tests based on the information given in the training manual; or (3) in some cases, successfully completing an appropriate Navy school.

Do not overlook the section of NAVTRA 10052 which lists the required and recommended references relating to the military qualification standards for advancement. Personnel of ALL ratings must complete the mandatory military requirements training manual for the appropriate rate level before they can be eligible to advance.

The references in NAVTRA 10052 which are recommended but not mandatory should also be studied carefully. ALL references listed in NAVTRA 10052 may be used as source material for the written examinations, at the appropriate rate levels.

Rate Training Manuals

There are two general types of rate training manuals. RATING manuals (such as this one) are prepared for most enlisted ratings. A rating manual gives information that is directly related to the occupational qualifications of ONE rating. SUBJECT MATTER manuals or BASIC manuals give information that applies to more than one rating.

Rate training manuals are revised from time to time to keep them up-to-date technically. The revision of a rate training manual is identified by a letter following the NAVTRA number. You can tell whether any particular copy of a training manual is the latest edition by checking the NAVTRA number and the letter following this number in the most recent edition of the List of Training Manuals and Correspondence Courses, NAVTRA 10061. (NAVTRA 10061 is actually a catalog that lists all current training manuals and correspondence courses; you will find this catalog useful in planning your study program.)

Each time a rate training manual is revised, it is brought into conformance with the official publications and directives on which it is based; but during the life of any edition, discrepancies between the manual and the official sources are almost certain to arise because of changes to the latter which are issued in the interim. In the performance of your duties, you should always refer to the appropriate official publication or directive. If the official source is listed in NAVTRA 10052, the Naval Examining Center uses it as a source of questions in preparing the fleetwide examinations for advancement. In case of discrepancy between any publications listed in NAVTRA 10052 for a given rate, the Examining Center will use the most recent material.

Rate training manuals are designed to help you prepare for advancement. The following suggestions may help you to make the best use of this manual and other Navy training publications when you are preparing for advancement.

1. Study the military qualifications and the occupational qualifications for your rating before you study the training manual, and refer to the quals frequently as you study. Remember, you are studying the manual primarily in order to meet these quals.

2. Set up a regular study plan. It will probably be easier for you to stick to a schedule if you can plan to study at the same time each day. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the manual intensively, become familiar with the entire book. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the book without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training manual in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a pretty clear picture of the scope and content of the book. As you look through the book in this way, ask yourself such questions as:

- What do I need to learn about this?
- What do I already know about this?
- How is this information related to information given in other chapters?
- How is this information related to the qualifications for advancement?

5. When you have a general idea of what is in the training manual and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. The amount of material that you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit—chapter, section, or subsection—write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training manual to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without looking at the training manual, write down the main ideas that you have gotten from studying this unit. Don't just quote the book. If you can't give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use enlisted correspondence courses whenever you can. The correspondence courses are based on rate training manuals or on other appropriate texts. As mentioned before, completion of a mandatory rate training manual can be accomplished by passing an enlisted correspondence course based on the rate training manual. You will probably find it helpful to take other correspondence courses as well as those based on mandatory manuals. Taking a correspondence course helps you to master the information given in the training manual, and also helps you see how much you have learned.

10. Think of your future as you study rate training manuals. You are working for advancement to third class or second class right now, but some day you will be working toward higher rates. Anything extra that you can learn will help you—both now and later.

SOURCES OF INFORMATION

Besides training manuals, NAVTRA 10052 lists official publications on which you may be examined. Make sure you study the sections required.

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the occupational qualifications of your rating.

Some publications are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance; it is likely to be a waste of time, and may even be seriously misleading.

GOVERNMENT PUBLICATIONS

There are various government publications which you may find useful as sources of reference. A number of publications issued by the Naval Facilities Engineering Command (NAVFAC) which will be of interest to personnel in the Group VIII ratings are listed in the Index of Naval Facilities Engineering Command Publications, NAVFAC P-349 (updated semiannually). A publications program is one of the principal communications media used by NAVFAC to provide a ready reference of current technical and administrative data for use by its subordinate units. NAVFAC publications are listed in alphabetical and numerical order in NAVFAC P-349; copies of NAVFAC P-349 may be obtained through proper channels from the U. S. Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.

Some of the training publications that you will need to study or refer to as you prepare for advancement have already been discussed in this chapter. Two additional publications that you may find useful are listed below.

Tools and Their Uses, NavPers 10085

Blueprint Reading and Sketching, NavPers 10077

In addition, you may find it useful to consult the rate training manuals prepared for other Group VIII (Construction) ratings. References to these manuals will add to your knowledge of the duties of other men in the Construction ratings.

Some of the U. S. Army technical manuals (TMs) may contain information that will help you in your work. TMs are easily ordered through the normal naval supply procurement system after consulting DA PAM 310-4 (the Department of the Army index of technical manuals) for the correct title, number, and date.

COMMERCIAL PUBLICATIONS

A wealth of information of concern to persons in the construction field is contained in reports, pamphlets, handbooks, and texts published by manufacturers, trade associations, technical and professional societies, and commercial publishing houses. Much of this literature will be available to you at the station library, the Public Works Department, or the battalion office or library.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. Training films are listed in the United States Navy Film Catalog, NAVAIR 10-1-777 (formerly NAVWEPS 10-1-777), published in 1969. Copies may be ordered in accordance with the Navy Stock List of Forms and Publications, NAVSUP 2002. Supplements to the Film Catalog are issued as applicable.

When selecting a film, note its date of issue listed in the Film Catalog. As you know, procedures sometimes change rapidly. Thus, some films become obsolete rapidly. If a film is obsolete only in part, it may sometimes be shown effectively if before or during its showing you carefully point out to trainees the procedures that have changed.

DESIGNATION OF SOURCE, SUBJECT AND EDITION

Official publications and directives carry abbreviations and numbers which identify the source of the document and its subject matter. This training manual, for instance, is NAVTRA 10656-F, which means that it is a publication of the Naval Training Support Command, a rate training manual in the Group VIII rating structure. The letter following the numerals designates the edition (the date of publication is printed on the preface page). Because you should always make it your responsibility to see that you are using the latest edition of any publication or directive, we usually do not show the final letter when referring to a publication or directive in this training manual. ALWAYS USE THE LATEST EDITION.

CHAPTER 2
ADMINISTRATIVE DUTIES AND SAFETY RESPONSIBILITIES

As a UT 3 or 2 you still have a great deal to learn about your trade, including the development of skills required in performing tasks concerning equipment operation, maintenance, and adjustments. However, you will be called upon from time to time to fill the role of supervisor. Your duties and responsiblities as a supervisor will be limited, but they will gradually increase as you advance from one pay grade to the next. This chapter discusses two major responsibilities of concern to supervisors—administration and safety. It is not intended to tell you all you need to know about these two subjects, but to give you some idea of what you, as a UT 3 or UT 2, can expect in the way of administrative duties and safety responsibilities. As part of this chapter, information also is included on Navy Enlisted Classification Codes (NECs) available to UTs and the purpose of the Personnel Readiness Capability Program.

ASSIGNMENT AS CREW LEADER

As you gain experience in utilities work, you will probably be called upon to serve as crew leader of UT teams (or crews) consisting of 3 to 5 men. These teams may perform various types of work, such as measure, cut and thread pipe; install pipe lagging and other insulative and protective materials on pipe; or clean watersides and firesides of boilers. Your duties as a crew leader may vary from one activity to another. At most activities, however, a crew leader's duties may involve planning work assignments, supervising work teams, initiating requisitions, and keeping time cards. Information that will aid you in carrying out these duties is given below.

PLANNING WORK ASSIGNMENTS

For purposes of this duscussion, planning is the process of determining requirements and devising and developing methods and schemes of action for construction of a project. Proper planning saves time and money for the Navy and makes the job easier for all concerned. Some pointers that will aid you in planning day-to-day work assignments for work teams are given below.

When you are assigned a job, whether in writing or orally, one of the first things to do is to make sure you understand clearly just what is to be done. Study plans and specifications where applicable. If you have any questions, find out the answers from those in a position to supply the information you need. Among other things, make sure you understand the priority of the project, time of completion, and any special instructions to be followed.

In planning for a small or large project, you must consider the capability of the men available for assignment. Determine who is to do what and how long it should take to complete the job. Realizing that idleness may breed discontent, arrange to have another job ready for starting as soon as the first one is finished.

Establish goals for each work day and encourage your men to work together as a team in accomplishing these goals. You want your goals to be such that your men will be kept busy, but make sure they are realistic. During an emergency, most men will make a tremendous effort to meet the deadline. But men are not machines, and when there is no emergency, they cannot be expected to continuously achieve an excessive high rate of production. In your planning, you must also allow for things which are not considered as direct labor, such as safety training, disaster control training, leave, and liberty.

To help ensure that the job is done properly and on time, you will want to consider the method to use in accomplishing the job. If there is more than one way of doing a particular job, make sure the method you select is the best way. After selecting a method, analyze it to see if it could be simplified with a resultant savings in time and effort.

Plan material requirements so that you will not have a lot of materials left over. But don't have your material estimate so low that you might run out of necessary items and the job be delayed, and your men have to stand around idle, until new supplies can be obtained. At times, circumstances come about that make it necessary to use more materials than anticipated, so it's better to have some materials left over than run short.

Consider the tools and equipment you will need for the job and arrange to have them available at the place where the work is to be done, and at the time the work is to get underway. Determine who will use the tools, and make sure the men to whom they are assigned know how to use them properly and safely. Plan to have the materials so that they will be in an accessible place but not pose a safety hazard.

SUPERVISING WORK TEAMS

After a job has been properly planned, it is necessary to supervise the job carefully to ensure that it is completed properly and on time. Some pointers that will aid you in supervising work teams are given below.

Prior to starting a job, make sure your men know what is to be done. Give instructions clearly, and urge your men to ask questions on any points that are not clear to them. Be sure the men know all pertinent safety precautions and wear safety apparel where required. Check all tools and equipment before use to ensure they are in safe condition. Do not permit the use of dangerously defective tools and equipment; see that they are turned in for repair immediately.

While the job is underway, check from time to time to ensure that the work is progressing satisfactorily. Determine if the proper methods, materials, tools and equipment are being used. If a man is doing a job wrong, stop him and point out what he is doing wrong. Then explain the correct procedure and check to see that he follows it. In checking the work of your men, try and do it in such a way that your men will feel that the purpose of your inspection is to teach, guide and direct, rather than to criticize and find fault.

The supervisor should make sure that his men observe all applicable safety precautions and wear safety apparel when required. He should also watch for hazardous conditions, improper use of tools and equipment, and unsafe work practices which could cause accidents and possibly result in injury to personnel. Many young men are heedless of danger, or think a particular regulation is unnecessary. Very often such persons get hurt.

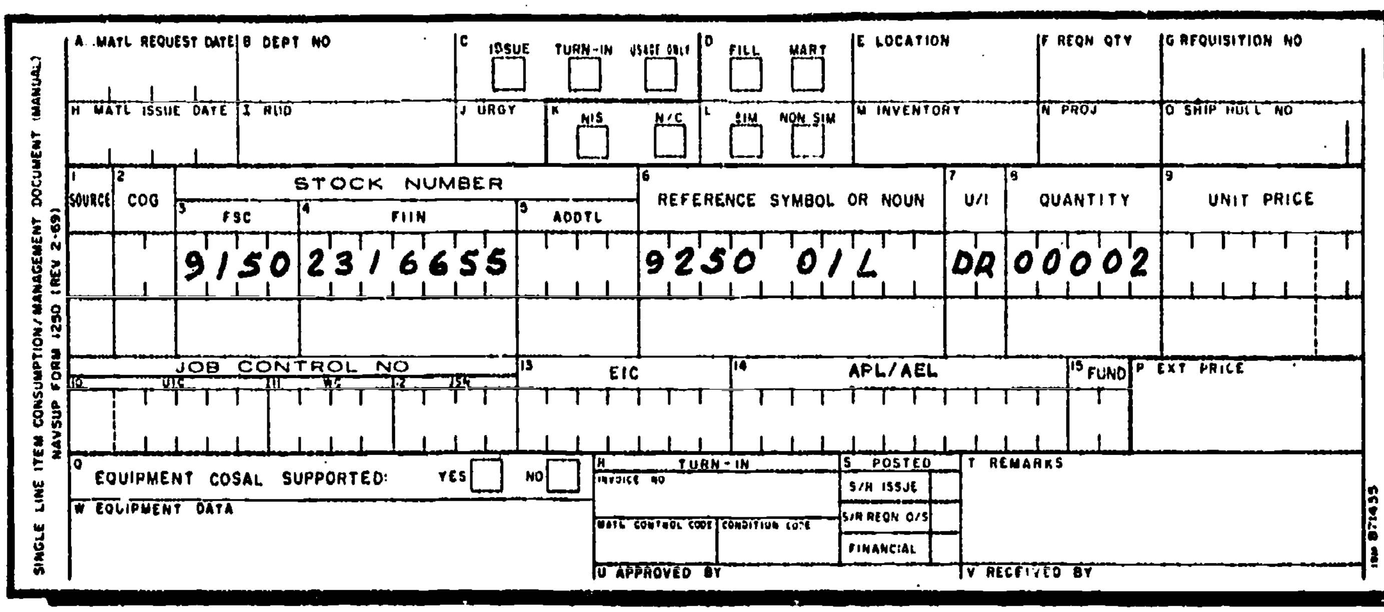
When time permits, rotate the men on various jobs. Rotation gives them varied experience and will help ensure your having men who can do the work if someone is hospitalized, transferred, or goes on leave.

A good supervisor should be able to get others to work together in getting the job accomplished. He should maintain an approachable attitude towards his men, making them feel free to come and seek his advice when in doubt as to any phase of the project. Emotional balance is especially important; a supervisor cannot become panicky before his men, unsure of himself in the face of conflicting forces, or pliable with influence. He should use tact and courtesy in dealing with his men and not show partiality to certain members of the work team. He should keep his men informed on matters that affect them personally or concern their work. He should also seek to maintain a high level of morale, keeping in mind that low morale can have a definite effect upon the quantity and quality of work turned out by his men.

The above is only a brief treatment on the subject of supervision. As you advance in rate you will be spending more and more of your time in supervising others, so let us urge that you make a continuing effort to learn more about the subject. Study books on supervision as well as leadership. Also, read articles on topics of concern to supervisors — such as safety, training, job planning, etc. — that appear from time to time in trade journals and other publications. There is a big need in the Navy for petty officers who are skilled supervisors. So consider the role of supervisor a big challenge and endeavor to become proficient in all areas of the supervisor's job.

PREPARING REQUISITIONS

As a crew leader, you should become familiar with requisition forms, which are orders from one activity requesting material or service from another activity. The most common method of requisitioning involves the use of printed forms which are designed to provide all necessary information for physical transfer of the material and accounting requirements.



17.84

Figure 2-1.—Single Line Item Consumption/Management Document (Manual), NavSup Form 1250.

Two forms used for requisitioning materials are the Single Line Item Consumption/Management Document (Manual), NavSup Form 1250 (fig. 2-1) and the Requisition and Invoice/Shipping Document, DD Form 1149 (fig. 2-2).

As a crew leader, you are not usually required to make up the entire NavSup Form 1250; however, you must list the item's stock number (when available), quantity, and name or description of each item needed. This form (NavSup Form 1250) is turned in to the expediter who will check it over, completing the other information, sign and then forward it to the Material Liaison Officer (MLO) or Supply Department for processing.

You are not likely to use DD Form 1149 very often. The items most frequently ordered on DD Form 1149 are bulk fuels and lubricants. This form is limited to a single page and must contain no more than nine line items. DD Form 1149 has many uses. It is not necessary to fill in all the blocks when this form is used as a requisition.

In requisitioning material you will need to know about the Federal Supply Classification (FSC) system. Information on the FSC system and other topics relating to supply is given in Military Requirements for Petty Officer 3 & 2, NavPers 10056-C. If necessary, review material on supply in NavPers 10056-C before going on to the next chapter.

TIMEKEEPING

In a battalion overseas, as well as at shore-based activities, your duties may involve the posting of entries on time cards for both military and civilian personnel. Therefore, you should know the types of information called for on time cards and understand the importance of accuracy in labor reporting. Here, we are primarily interested in the labor reporting system used in the battalion. You will find, however, that the system employed at shore-based activities is similar to that used in the battalion.

In order to record and measure the number of man-hours the unit spends on various functions, a labor accounting system is mandatory. This system must permit the day-to-day accumulation of labor utilization data in sufficient detail and in a manner that allows ready compilation of information required by the Operations Officer in the management of the manpower resources, and in the preparation of the various reports to higher authority.

While the system may vary slightly from one unit to another, they are so similar that the one described in this manual can be considered as being typical for all units.

The unit must account for all labor expended in carrying out assigned tasks and functions. This accounting must include the work performed by the reporting unit and, when applicable, work performed by civilian labor and the

SHIPPING CONTAINER TALLY → 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

REQUISITION AND INVOICE/SHIPPING DOCUMENT

SHEET NO.	1
NO. OF SHEETS	1
5. REQUISITION DATE	8 Dec 1972
6. REQUISITION NUMBER	0450A1 / 1
1. FROM:	EQUIPMENT DIVISION, NAVSCOLCONST
7. DATE MATERIEL REQUIRED	9 DEC 1972
8. PRIORITY	10
2. TO:	SUPPLY DEPT. U.S. NAVAL SCHOOLS CONSTRUCTION CBC, DAVISVILLE, R.I.
9. AUTHORITY OR PURPOSE	D.A. Parker, EOC, USN
10. SIGNATURE	
11a. VOUCHER NUMBER AND DATE	
b.	
3. SHIP TO - MARK FOR	M/F NAVSCOLCONST GREASE RACK
12. DATE SHIPPED	
13. MODE OF SHIPMENT	
14. BILL OF LADING NUMBER	
15. AIR MOVEMENT DESIGNATOR OR PORT REFERENCE NO.	

4. APPROPRIATION SYMBOL AND SUBHEAD	OBJECT CLASS	EXPENDITURE ACCOUNT (From)	(To)	CHARGEABLE ACTIVITY	BUREAU CONTROL ACTIVITY NO.	BUREAU CONTROL NO.	AMOUNT

ITEM NO. (a)	FEDERAL STOCK NUMBER, DESCRIPTION, AND CODING OF MATERIEL AND/OR SERVICES (b)	UNIT OF ISSUE (c)	QUANTITY REQUESTED (d)	SUPPLY ACTION (e)	TYPE CONTAINER (f)	CONTAINER NOS. (g)	UNIT PRICE (h)	TOTAL COST (i)
1	9150-190-0905, GREASE, AUTOMOTIVE PLUS ARTILLERY (GAA)	CN	5					
2	9150-231-6655, LUBE OIL, ENGINE (9250)	DR	2					

16. TRANSPORTATION VIA MATS OR MSTS CHARGEABLE TO

17. SPECIAL HANDLING

18. RECAPITULATION OF SHIPMENT	TOTAL CONTAINERS	TYPE CONTAINER	DESCRIPTION	TOTAL WEIGHT	TOTAL CUBE
ISSUED BY					
CHECKED BY					
PACKED BY			← TOTAL →		

19. RECEIPT	DATE	BY	
CONTAINERS RECEIVED EXCEPT AS NOTED			SHEET TOTAL
QUANTITIES RECEIVED EXCEPT AS NOTED			GRAND TOTAL
POSTED			20. RECEIVER'S VOUCHER NO.

DD FORM 1 MAR 58 1149 (11 PT) 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

REPLACES EDITION OF 1 MAY 58 WHICH MAY BE USED

2

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Figure 2-2. —Requisition and Invoice/Shipping Document, DD Form 1149.

military personnel of other activities. Labor expenditures must be accumulated under a number of reporting categories. This degree of reporting detail is required to provide the management data necessary to determine labor expenditures on project work for calculation of statistical labor costs, and comparison of actual construction performance with estimating standards. It also serves to determine the effectiveness of labor utilization in performing administrative and support functions, both for internal unit management and for development of planning standards by higher command.

For timekeeping and labor reporting purposes, total labor is considered as being either in one of two categories, i.e., productive or overhead. PRODUCTIVE LABOR includes all labor that directly or indirectly contributes to accomplishment of the unit's mission, including construction operations, military operations, and training. Productive labor is accounted for in two categories: direct and indirect labor.

1. DIRECT LABOR includes all labor expended directly on assigned construction tasks, either in the field, or in the shop, and that which contributes directly to the completion of the end product. Direct labor must be reported separately for each assigned construction item.

2. INDIRECT LABOR comprises labor required to support construction operations, but which does not produce an end product itself.

OVERHEAD LABOR is not considered to be productive labor in that it does not contribute directly or indirectly to the end product. It includes all labor that must be performed regardless of the assigned mission.

During the planning and scheduling of a construction project, each phase of the project considered as direct labor is given an identifying code, usually by the Operations Department. For example, "clearing and grubbing of site" may be assigned code R-15, "trenching" R-16, "pipe laying" R-17, etc. Due to the many types of construction projects encountered and different operations involved, codes for direct labor reporting may vary widely from one activity to another. The crew leader uses direct labor codes in reporting the hours spent by each member of his crew during each work day on assigned construction tasks.

Codes also are used to report time spent by crew members in the following categories: indirect labor, military operations and readiness, disaster control operations, training, and overhead labor. You will find the codes shown in figure 2-3 used at most activities to indicate time spent in these categories.

The crew leader's report is submitted on a daily labor distribution report form such as that shown in figure 2-4. The report is prepared by the crew leader for each phase of the construction project that his crew is involved with, and immediately provides a breakdown by manhours of the activities in the various labor codes for each man in the crew for any given day on any given project. It should be reviewed at the company level by the Platoon Commander, the Assistant Company Commander, and the Company Commander, and should be initialed by the Company Commander before it is forwarded to the Operations Department. It will be tabulated by the Management Division of the Operations Department, along with all of the daily labor distribution reports received from each company and department in the unit. It serves as the means by which the Operations Officer analyzes the labor distribution of his total manpower resources for any given day, and as feeder information for the preparation of the monthly operations report, and any other resource reports required of the unit.

Bear in mind that this information must be accurate and timely, and that each level in the company organization should review it for an analysis of its own internal construction management and performance, rather than having it serve merely as a feeder report to the Operations Officer.

SAFETY DUTIES OF SUPERVISORY PERSONNEL

Safety is a matter of chief concern to every supervisor. The supervisor who can continuously boast an outstanding safety record for his shop or field work team has a lot to be proud of. Safety precautions relating to specific operations performed by the UT are presented in various portions of this training manual. In this discussion, we are concerned with the safety organization of a mobile construction battalion, safety training responsibilities of a Crew Petty Officer, and the reporting procedures which the Crew Petty Officer must carry out if a subordinate is involved in an accident. Although these responsibilities may seem somewhat distant now, the sooner you start thinking about them, the better prepared you will be when it comes time to assume them. If you are a UT3 studying for advancement to

PRODUCTIVE LABOR. Productive labor includes all labor that directly contributes to the accomplishment of the Naval Mobile Construction Battalion, including construction operations and readiness, disaster recovery operations, and training.

DIRECT LABOR. This category includes all labor expended directly on assigned construction tasks, either in the field or in the shop, and which contributes directly to the completion of the end product.

INDIRECT LABOR. This category comprises labor required to support construction operations, but which does not produce in itself. Indirect labor reporting codes are as follows:

- X01 Construction Equipment Maintenance, Repair and Records
- X02 Operation and Engineering
- X03 Project Supervision
- X04 Project Expediting (Shop Planners)
- X05 Location Moving
- X06 Project Material Support
- X07 Tool and Spare Parts Issue
- X08 Other

MILITARY OPERATIONS AND READINESS. This category comprises all manpower expended in actual military operations, unit embarkation, and planning and preparations necessary to insure unit military and mobility readiness. Reporting codes are as follows:

- M01 Military Operations
- M02 Military Security
- M03 Embarkation
- M04 Unit Movement
- M05 Mobility Preparation
- M06 Contingency
- M07 Military Administrative Functions
- M08 Mobility & Defense Exercise
- M09 Other

DISASTER CONTROL OPERATIONS

- D01 Disaster Control Operations
- D02 Disaster Control Exercise

TRAINING. This category includes attendance at service schools, factory and industrial training courses, fleet type training, and short courses, military training, and organized training conducted within the battalion. Reporting codes are as follows:

- T01 Technical Training
- T02 Military Training
- T03 Disaster Control Training
- T04 Leadership Training
- T05 Safety Training
- T06 Training Administration

OVERHEAD LABOR. This category includes labor which must be performed regardless of whether a mission is assigned, and which does not contribute to the assigned mission. Reporting codes are as follows:

- Y01 Administrative & Personnel
- Y02 Medical & Dental Department
- Y03 Navy Exchange and Special Services
- Y04 Supply & Disbursing
- Y05 Commissary
- Y06 Camp Upkeep & Repairs
- Y07 Security
- Y08 Leave & Liberty
- Y09 Sickcall, Dental & Hospitalization
- Y10 Personal Affairs
- Y11 Lost Time
- Y12 TAD not for unit
- Y13 Other

133.417(54F)

Figure 2-3.—Sub-categories of labor.

UT2, then you can reasonably expect to assume these duties in the near future.

BATTALION SAFETY ORGANIZATION

As a supervisor in a mobile construction battalion, you should have a knowledge of the safety organization of the battalion. This is important since you cannot function as a Crew Petty Officer in an intelligent and informed manner unless you are aware of how you fit into the battalion's scheme of safety. In other words, you should know who (or what group) in the battalion arbitrates and establishes the safety policies and procedures you must follow. You should also know who will be your source

CREW LEADER: JOHNSON UT2 | CREW: PIPE LAYING | CREW SIZE: 6 | TRANSFERS THIS DATE: NONE

PROJECT: FLEET RECREATION FACILITY-SEWAGE DISTRIBUTION SYSTEM | DATE: 11 JAN 19__

NAME	PRODUCTIVE LABOR CODE: DIRECT R 17	INDIRECT (X) X 01	OTHER (M. D. T) T 04	T 05	OVERHEAD LABOR CODE (Y) Y 02	Y 11	
SIMPSON	6		1		1		8
BLUE	7			1			8
CARTER	7			1			8
FOX	6	2					8
BONE	6					2	8
SWEET	6					2	8
						TOTAL	48

DAILY LABOR DISTRIBUTION COMCBPAC-GEN-5300/1 (REV. 6-67)

54.335

Figure 2-4. —Daily labor distribution report form.

of safety guidance in training and supervising your men. In addition, you should know to whom your accident reports are routed, and more importantly, why this information is sought.

Every mobile construction battalion is required by COMCBLANT/COMCBPAC instructions to implement a formal safety organization (see fig. 2-5). The two principal agencies of this organization are the Safety Policy Committee and the Safety Division.

The SAFETY POLICY COMMITTEE is presided over by the Executive Officer and includes among its members the Operations Officer, Supply Officer, Personnel Officer, Medical Officer, Safety Officer, and any other members which the Commanding Officer may wish to appoint. As its name suggests, the primary purpose of the committee is to formulate safety doctrine and policy for the battalion. In order to do this, the committee must continually review and evaluate the work practices of the battalion, particularly in the light of accident analyses and reports, so as to be able to recommend practical and effective safety precautions.

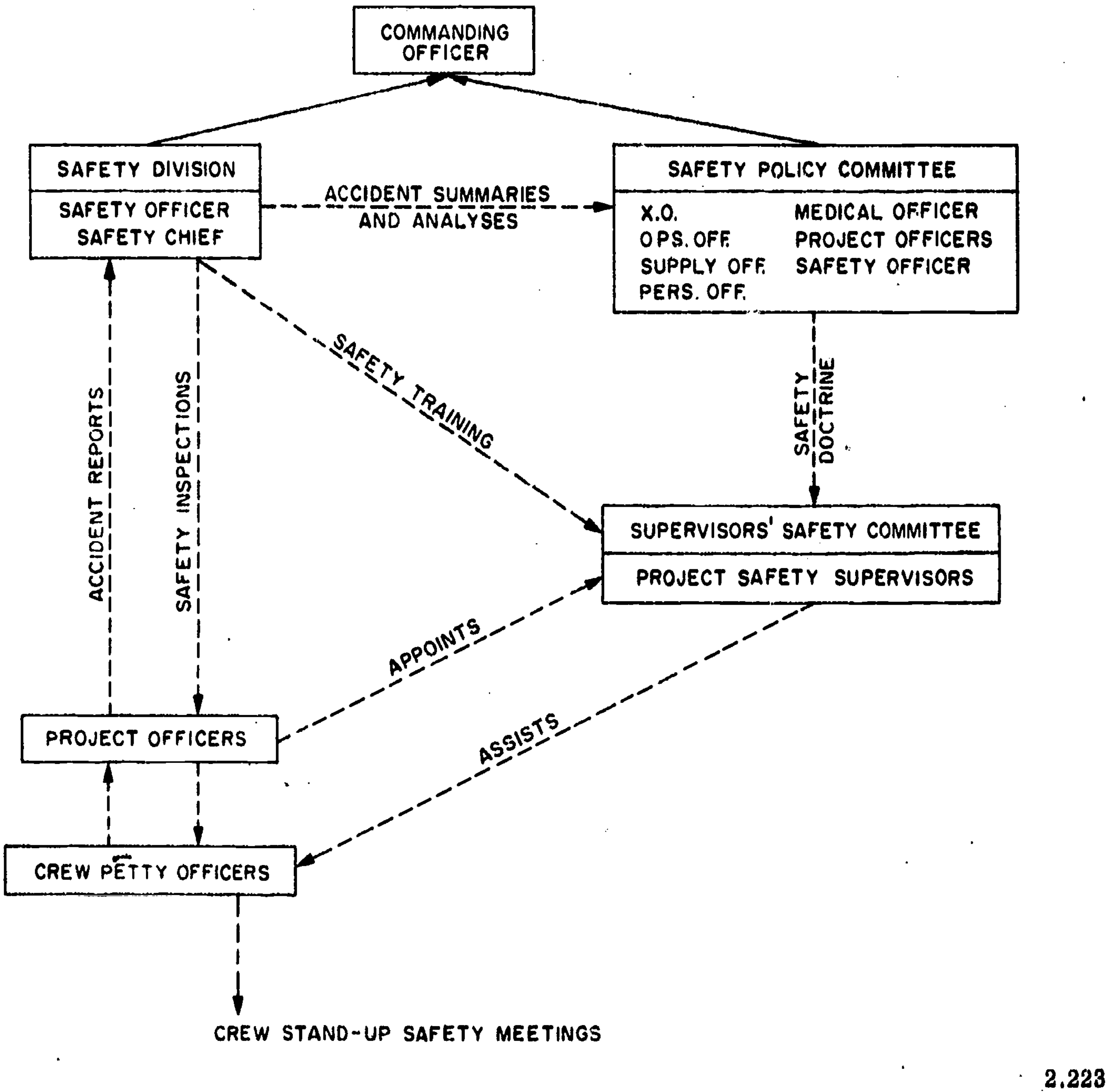


Figure 2-5.—NMCB safety organization.

The SAFETY DIVISION is detailed to ensure that the procedures established through the Safety Policy Committee are carried out properly and expeditiously throughout the battalion. The Safety Division is normally composed of the Safety Officer and the Safety Inspector (more commonly known as the Safety Chief), and whatever additional assistants are necessary. The position of Safety Officer is a collateral duty assigned to an officer by the Commanding Officer and under the direct supervision and control of the Operations Officer. Safety Chief, however, is a full-time position assigned to a Chief Petty Officer. Normally, the CPO selected to fill this position will be given formal indoctrination and training at the NMCB homeport prior to the deployment.

Perhaps the foremost responsibility of the Safety Division is to constantly survey and inspect the battalion for unsafe practices and conditions. It is in this area that the Safety Officer utilizes the Safety Chief to best advantage, since it is the latter's responsibility to systematically visit and inspect every job site, shop, camp, and galley throughout the battalion. The Safety Chief's job is, however, much more than just being a safety monitor. He also acts as an advisor and consultant during his rounds, meeting informally with supervisors to answer questions and help develop and encourage safe practices. Both the Safety Officer and the Safety Chief have the authority, and duty, to stop any operation or practice that might cause injury to personnel or damage to material or equipment.

The Safety Division, under the Safety Officer, is also responsible for receiving and reviewing all accident reports and for preparing summaries and analysis of these reports. The Safety Officer also reviews the supervisor's proposals for corrective action and recommends acceptance of these proposals when appropriate.

Another important function of the Safety Division is the implementation of a safety training program throughout the battalion. It might be emphasized, in this connection, that the Safety Division (Safety Officer) will be your primary source of safety information and guidance. This information and guidance will be disseminated to you through your Project Safety Supervisor—who we will discuss in a moment. The Safety Officer, frequently with the assistance of the Educational Services Officer, provides for safety lectures, instructions, demonstrations, and many other activities centered on safety, such as safety movies, safety awards ceremonies, and placement of safety posters. As part of this safety training program, the Safety Officer is also responsible for organizing and coordinating the crew-level safety briefings, called Stand-Up Safety Meetings, which are conducted by the crew supervisor or Crew Petty Officer. More will be said about these meetings shortly.

A third safety group established in every NMCB, and the one with which you, as a petty officer and supervisor, will perhaps have the most direct contact, is the SUPERVISORS' SAFETY COMMITTEE. This committee is composed of all the Project Safety Supervisors in the battalion. It might be well to pause here and explain that prior to the deployment of a NMCB, the construction expected of the battalion is identified and organized into units of work called projects. Each project is given a number and assigned a Project Officer (often a Chief Petty Officer), who has overall responsibility for the safe and successful completion of the project. To assist him in maintaining the necessary safety programs in his project, the Project Officer selects a capable Petty Officer, First or Second Class, and assigns him the collateral duty of Project Safety Supervisor. The duties of the Project Safety Supervisor are rather considerable. If you should become a Crew Petty Officer, the Project Safety Supervisor will be your primary contact in practically all matters concerning safety. For the moment, however, we are interested in him as a member of the Supervisors' Safety Committee.

The purpose of this last committee is to act as a focal point for the exchange of safety information and policies between the various projects. Since crews from different projects often work in close proximity, the hazards peculiar to the work of one crew sometimes affect the other, and vice versa. The Supervisors' Safety Committee thus provides a convenient forum where one project can apprise the others of its work procedures and related safety precautions. The committee also forms a convenient avenue by which any crew, or any individual, can forward recommendations for improved safety methods to the Safety Policy Committee.

The Safety Division, the Safety Policy Committee, and the Supervisors' Safety Committee together make-up the formal safety organization of a NMCB; that is, those groups whose duties and functions center solely on safety. As a petty officer, however, and particularly as a Crew Petty Officer supervising a job, you will be preoccupied with many other responsibilities besides safety. Nevertheless, the fact remains that the ultimate achievement of safety in the NMCB rests with you. In truth, the Safety Division, the Safety Policy Committee, and the Supervisors' Safety Committee all operate to support you as a supervisor.

SAFETY DUTIES OF A SUPERVISOR

Every petty officer is responsible for the safety of personnel placed in his charge. Basically, your safety duties as a supervisor will revolve around training your subordinates, correcting unsafe practices and conditions should they occur, and being prepared to execute certain procedures should one of your men be involved in an accident.

Safety Training

New methods and procedures used in performing construction operations, and working in new and different situations, all require the supervisor to keep himself and his men informed of the latest in construction safety. Moreover, you can never assume that men transferred to your crew from some other crew are appropriately and fully trained in safety matters. For these reasons, the safety education and training of subordinates is a continuing responsibility of every supervisor.

To keep his men informed, every Crew Petty Officer periodically holds short (approximately 5 to 15 minute) safety meetings, called Stand-Up Safety Meetings, during which he briefs his crew on hazards and precautions relating to current work. Although the Crew Petty Officer is responsible for the actual conduct of the meetings, much of the content of the briefing is organized and assembled by the Safety Division and disseminated to the Crew Petty Officer through his Project Safety Supervisor.

In addition to the Stand-Up Safety Meetings, the Crew Petty Officer is, of course, also concerned with the incidental, day-to-day instruction and training of his men on the job. It is beyond the scope of this text to go into a discussion of teaching or training methods (see chapter 7, Military Requirements for Petty Officer 3 & 2, NavPers 10056-C). However, a few words on the petty officer's approach to safety and safety training at the crew level might be appropriate. The job of achieving safety in your crew is, like most other supervisory functions, essentially a matter of leadership. In studying and seeking to understand the practical aspects of directing and managing men, many new petty officers fail to recognize the power of personal example in leading and teaching subordinates. You will soon discover, in this regard, that subordinates are very quick to detect any difference between what you say and what you do. You cannot reasonably expect your men to measure up to standards of safety conduct and awareness which you yourself do not constantly DEMONSTRATE. It is not enough to be knowledgeable in the various aspects of construction safety. As a supervisor, you must make your genuine concern for the importance of crew safety visible and known to your men at all times. Leadership by example may not be the only technique of leadership, but it is one of the most eminently practical and time-proven methods of management available to you.

Accident Reporting Procedures

A well planned and conscientiously executed crew safety program will prevent accidents. Nevertheless, you must be prepared to carry out certain procedures should a man in your charge be injured or otherwise involved in an accident. It might be mentioned that for the purpose of accident reporting, an accident is defined as "Any unplanned act or event which results in damage to property, material or equipment and/or cargo, or personnel injury or death when not the result of hostile action." For purposes of this discussion, an injury may be defined as "Any physical impairment which prevents a Navy military person from performing his regularly established duty or work for a period of 24 hours or more subsequent to 2400 hours on the day of the injury." If an injury is the type which requires first aid or medical attention and the man can be returned to duty within 24 hours, or can resume some light form of work within 24 hours, the formal investigation and reporting procedures ordinarily will not be necessary. This is not to say, however, that you need not investigate these kinds of accidents on your own initiative. Small or seemingly harmless incidents often repeat themselves with more serious results. If an improper practice or condition exists in your crew, you must obviously identify and correct it before a serious accident occurs.

Supposing one of your men is injured, the first priority of course is to arrange for prompt medical treatment. At the same time, you must also take steps to prevent additional injuries or damage by shutting off power, stopping equipment or machinery, posting guards, and so on. Next, see to it that the Project Officer is notified of the accident. If the accident occurs outside of working hours, then the Officer of the Day is notified. If the accident is one that causes any physical impairment which will prevent the man from performing his regularly established duty for a period of 24 hours or more subsequent to 2400 of the day of injury, then it may be your responsibility as Crew Petty Officer to investigate the circumstances and submit a written report. The form you will use to report the accident is Accidental Injury/Death Report, OPNAV Form 5100/1, which supersedes the Accident Report, NAVEXOS Form 108. It is important to note that this reporting requirement is in effect at all times. However, if one of your crew members is injured during nonworking hours, the Safety Chief is responsible for conducting the investigation and submitting the report.

Figures 2-6 and 2-7 show the front and back, respectively, of the Accidental Injury/Death Report, OPNAV Form 5100/1. A supply of these forms is made available to each Crew Petty

ACCIDENTAL INJURY/DEATH REPORT
OPNAV FORM 5100/1 (5-69) S/N-0107-776-0010
SPECIAL HANDLING REQUIRED IN ACCORDANCE WITH OPNAVINST 5100.11

FOR OFFICIAL USE ONLY
REPORT SYMBOL OPNAV 5100-3

TO: COMMANDER, NAVAL SAFETY CENTER, NAVAL AIR STATION, NORFOLK, VA. 23511

1. REPORTING COMMAND
2A. COMMAND AUTHORITY EXERCISED BY:
2B. GCM AUTHORITY EXERCISED BY:
3. REPORT NUMBER

4. NAME OF PERSON INJURED/KILLED (FIRST, MIDDLE, LAST)
5A. SERVICE/BADGE NO.
5B. SOCIAL SECURITY NO.
6. RANK & DESIGNATOR/RATE AND NEC/CIVILIAN OCCUPATION

7. SEX
8. AGE
9A. TIME IN SERVICE (MIL ONLY)
9B. YEARS EXPERIENCE (CIV ONLY)
10A. MIL: ☐ USN ☐ USNR ☐ OTHER
10B. CIV: ☐ EMPLOYEE ☐ DEPENDENT ☐ OTHER

11A. DUTY STATUS
MIL ☐ EXT ACT DU ☐ ACDUTRA ☐ DRILL ☐ TRAVEL
☐ LV/LIB ☐ UA ☐ OTHER
11B. DUTY STATUS
CIV: ☐ REG. ☐ TEMP. ☐ TRAVEL
☐ UNAUTH WORK ☐ OTHER

12. DATE AND TIME OF INJURY

HOUR	DATE	MONTH	YEAR	DAY OF WEEK

13. PLACE OF OCCURRENCE
☐ ABOARD SHIP ☐ ASHORE
DESCRIBE LOCATION
14. DAYS LOST/CHARGED

15. WEATHER/NATURAL DISASTER
16. LIGHT CONDITIONS AT SITE

17. DESCRIPTION OF EVENTS: (DESCRIBE THE CONTRIBUTING EVENTS LEADING UP TO THE INJURY/DEATH SO THAT THE REVIEWING OFFICIAL WILL HAVE A CLEAR PICTURE OF WHAT CAUSED THE INJURY/DEATH, SELECT THE APPROPRIATE ENTRY FROM EACH MAJOR FACTOR CATEGORY LISTED ON BACK OF INSTRUCTION SHEET AND ENTER IT WITH AMPLIFYING DETAIL IN BOXES 18 THROUGH 25 BELOW.)

WITNESSES: NAME, RANK/RATE, ADDRESS

18. KIND OF INJURY:
19. BODY PART INJURED:

20. SOURCE OF INJURY (OBJECT, SUBSTANCE, ETC. WHICH CONTACTED THE BODY AND INJURED PERSON):
21. KIND OF ACCIDENT (FALL, CRUSHED, STRUCK BY, ETC.):

22. HADARDOUS CONDITION (WHAT CONDITION CAUSED, PERMITTED, CONTRIBUTED TO ACCIDENT WHICH RESULTED IN INJURY): ☐ NOT APPLICABLE
23. AGENCY (AND AGENCY PART) OF ACCIDENT (OBJECT, SUBSTANCE, ETC. TO WHICH THE HAZARDOUS CONDITION APPLIED): ☐ NOT APPLICABLE

24. UNSAFE ACT (WHAT PERSONAL ACTION CAUSED OR ALLOWED ACCIDENT TO OCCUR): ☐ BY INJURED MAN ☐ BY ANOTHER ☐ NOT APPLICABLE
25. UNSAFE PERSONAL FACTOR (MENTAL OR PHYSICAL CONDITION WHICH RESULTED IN OR CONTRIBUTED TO THE UNSAFE ACT):

26. REASON FOR BEING ON GOVERNMENT PROPERTY (REGULAR DUTY ASSIGNMENT, CIV EMP, PATIENT, VISITOR, BUSINESS, ETC.):

D-33890

29.52.1(2D)

Figure 2-6.—Accidental Injury/Death Report, OPNAV Form 5100/1 (front).

OPNAV FORM 5100/1 (5-69) (BACK)

27. CORRECTIVE ACTION TAKEN/RECOMMENDED (WHAT ACTION WILL HELP PREVENT ANOTHER ACCIDENT OF THIS TYPE?)

28. SIGNATURE OF PERSON PREPARING REPORT	29. TITLE AND GRADE	30. DATE

31. REVIEW AND COMMENTS OF SAFETY OFFICER OR COMMANDING OFFICER

32. SIGNATURE	33. TITLE AND GRADE	34. DATE

ADDITIONAL INFORMATION WHEN REQUIRED BY JAG

35. CONDITION OF INDIVIDUAL AT TIME OF THIS OCCURRENCE:
UNDER THE INFLUENCE OF: ☐ ALCOHOL ☐ NARCOTICS ☐ BARBITURATES ☐ OTHER (SPECIFY) ________ ☐ NOT APPLICABLE
☐ UNABLE TO DETERMINE DUE TO PHYSICAL CONDITION EXAMINER ________

36. BASIS FOR ABOVE OPINION:
A. CLINICAL FINDINGS: ________
B. BIOLOGICAL SPECIMEN TAKEN: ☐ NO ☐ YES TIME ________ LABORATORY TO WHICH SPECIMEN SENT ________
TYPE OF TEST RESULT OTHER TESTS/RESULTS

37. MEDICAL OFFICER'S FINDINGS RELATIVE TO NATURE AND EXTENT OF INJURY:

38. WAS SUBJECT HOSPITALIZED AS A RESULT OF THIS OCCURRENCE? ☐ YES ☐ NO	39. IF THE SUBJECT WERE ALREADY ON THE SICK LIST FOR OTHER REASONS AT TIME OF INJURY WOULD THIS INJURY IN ITSELF HAVE REQUIRED HOSPITALIZATION? ☐ YES ☐ NO ☐ NOT APPLICABLE
40. IT IS POSSIBLE THAT THE FOLLOWING DISABILITY MAY RESULT: ☐ PERMANENT PARTIAL ☐ PERMANENT TOTAL	41. DATE OF EXPIRATION OF ENLISTMENT/TERM OF OBLIGATED SERVICE:

42. IF DECEASED, WAS AUTOPSY CONDUCTED? ☐ YES ☐ NO IF YES, ATTACH COPY OF AUTOPSY PROTOCOL

43. ADDITIONAL INFORMATION FOR RESERVISTS: IF RESERVIST WAS ENGAGED IN ACTIVE-DUTY TRAINING OR INACTIVE DUTY (DRILL) SUPPLY THE FOLLOWING INFORMATION:

MEMBER REPORTED FOR DUTY OR DRILL		DISMISSED FROM DUTY OR DRILL		INJURY	
DATE	TIME	DA	TIME	DATE	TIME

44. MEDICAL OFFICER'S SIGNATURE	45. GRADE	46. DATE

47. IT IS THE OPINION OF THE UNDERSIGNED THAT THE INJURY/DEATH IN QUESTION WAS INCURRED IN THE LINE OF DUTY AND NOT AS THE RESULT OF THE SUBJECT MAN'S OWN MISCONDUCT. ☐ YES ☐ NO

COMMANDING OFFICER (OR ONE AUTHORIZED TO SIGN BY HIS DIRECTION - IF LATTER SO INDICATE)

48. SIGNATURE	49. TYPED NAME AND GRADE	50. DATE

51. ACTION OF OFFICER EXERCISING GENERAL COURT-MARTIAL JURISDICTION:

DATE: ________

FROM:

TO: JUDGE ADVOCATE GENERAL OF THE NAVY

SIGNATURE AND TYPED NAME OF OFFICER EXERCISING GCM AUTHORITY (OR ONE AUTHORIZED TO SIGN BY DIRECTION)

0-33880

29.52.2(2D)

Figure 2-7. —Accidental Injury/Death Report, OPNAV Form 5100/1 (back).

Officer. The form must be filled out in triplicate and forwarded to the Safety Officer via your Project Officer within 24 hours of the accident.

An instruction sheet which accompanies OPNAV Form 5100/1 provides instructions for filling in various blocks on the form which are not self-explanatory. Figures 2-8 and 2-9 show the front and back, respectively, of this instruction sheet. Study the instruction sheet carefully and make sure you fill in all applicable items on the report properly and neatly. Remember that thorough investigations of accidents will help to identify and correct deficiencies, and reduce to a minimum injuries and deaths to personnel from accidental causes.

Accidental injuries or deaths under certain circumstances do not have to be reported on the Accidental Injury/Death Report, OPNAV Form 5100/1. If you have any questions as to when this report is required, routing instructions, and so on, consult your Project Safety Supervisor for advice on what to do in the matter.

THE PERSONNEL READINESS CAPABILITY PROGRAM

The Personnel Readiness Capability Program (PRCP) provides a standard means of identifying, collecting, processing, and utilizing information on all members of the Naval Construction Force, both active and reserve. This information can be used by all levels of management and supervision to determine a unit's readiness capability by comparing it to actual or planned requirements.

The majority of PRCP information consists of an inventory of individual skills acquired through formal or on-the-job training. A record of these skills, combined with other data from the service record, such as expiration of enlistment, rotation data, etc., provides a ready means of predicting future capabilities and requirements. Some of these may be:

a. Construction and military capabilities.
b. Personnel, logistics, and training requirements.
c. Berthing, messing, and housing requirements.
d. Contingency requirements.

The most important aspects of the Personnel Readiness Capability Program, at your level, are collecting and passing along skill information on yourself and your men. However, the initial PRCP skill inventory will be based upon an interview with your crew/squad leader or another senior petty officer of your rating.

Special PRCP Interviewer's Standards and Guides have been prepared to assist persons conducting interviews. Each "Guide" contains a detailed explanation of every skill identified in the PRCP. These definitions are now standard throughout the entire Naval Construction Force, and any man, regardless of duty assignment, can turn to these standards and know what is expected in a given skill area.

During an interview, it is imperative that you and your men discuss your capabilities openly and honestly. Remember, if you exaggerate, you may be depriving yourselves of valuable and needed training. Then too, you may be the one selected to do that special job all on your own. Will you be ready?

It will be the responsibility of your supervisors to provide you with the opportunity to learn new skills. This may be done through training or by assigning your team to various types of work whenever possible. You can help by learning what is required in the PRCP Interviewer's Standards and Guides for your rating; then, as you and your men satisfy those requirements, you can report this to your PRCP coordinator; and, he will have the information added to your inventory of capabilities. By keeping your PRCP record current, you can avoid the unpleasantness of attending training in areas you are already proficient in. Like practical factors, it is primarily your responsibility for seeing that this information is kept current and accurate. After all, you will be the first to feel that you are qualified in a new skill.

All PRCP information is ultimately stored in a computer data bank. People who work with computers have developed a very realistic saying: "Garbage in: Garbage out." In other words, the accuracy of reports devised for the Personnel Readiness Capability Program will only be as accurate as the information you provide.

NAVY ENLISTED CLASSIFICATION CODES

The Utilitiesman rating is a source of a number of NECs (Navy Enlisted Classification) codes. NECs reflect special knowledge and skills in certain ratings. The NEC Coding System is designed to facilitate management control over enlisted skills by accurately identifying billets and personnel. It also helps ensure maximum skill utilization in distribution and detailing. The NECs below may be earned by

ACCIDENTAL INJURY/DEATH REPORT
OPNAV FORM 5100/1 (5-69)

INSTRUCTIONS FOR ACCIDENTAL INJURY/DEATH REPORT

Print with pen or type; items not applicable or contributory to the injury/death will be marked N.A.

Block 1. Reporting Command - Self-explanatory.

Block 2A. Command Authority Exercised By. In the case of ships and air units this is the Type Commander. For shore activities this is the command that provides command and support (ie COMSERVLANT in the case of NAVSTA NORVA, COMNAVSHIPSYSCOM in the case of a ship yard, etc.)

Block 2B. GCM Authority Exercised By. Self-explanatory. Use only when report is required by JAG.

Block 3. Report Number. Reports will be serialized consecutively by each reporting command/activity during the fiscal year. (ie 2-69 is the second report of fiscal year 1969)

Block 4. Name of Person Injured/Killed. Self-explanatory.

Block 5A. Service/Badge Number. Self-explanatory.

Block 5B. Social Security Number. Self-explanatory.

Block 6. Rank & Designator/Rate & NEC/Civilian Occupation. Self-explanatory.

Block 7. Sex. Self-explanatory.

Block 8. Age. Self-explanatory

Block 9A. Time in Service (Mil Only). Indicate in years only.

Block 9B. Years Experience (Civ. Only). Indicate number of years experience in present occupation, including years of experience gained in that occupation in other government or private industry employment. In cases of injury or death to civilians other than employees of the Department of the Navy, mark "N.A.".

Block 10. Employment Status. In the event the line "Other" is selected for either military or civilian, specify as contract employee, visitor, Army, Air Force, etc.

Block 11. Duty Status. For either military or civilian check all applicable boxes.

Block 12. Date and Time of Injury. Give the hour on the basis of the 24 hour clock using four digits. Use two digits each for the date, month and year.

Block 13. Place of Occurrence. In describing the location enter paint locker, weather deck, flight deck, machine shop, galley, etc. as appropriate.

Block 14. Days Lost/Charged. For fatal injury or missing persons, enter 6000 days. For all other injuries enter the number of calendar days of disability, or time charges using the schedule of charges, Table 1, Appendix I. Whenever the schedule of charges is used the actual number of calendar days of disability is not entered.

Block 15. Weather/Natural Disaster. If a factor, describe weather conditions or natural disaster which contributed to the injury.

Block 16. Light Conditions at Site. Describe outside or internal lighting conditions, as applicable, existing at the immediate site and time of accident.

Block 17. Description of Events. Enter narrative description of circumstances and events which directly or indirectly led to the injury, physical impairment or death. Include sufficient information to clarify or expand upon the character and scope of data to be entered in blocks 18 through 25 of the report. Accidental injury/death reports in all cases resulting from a ship accident will reference the applicable ship accident report serial in this block. Include in this block, as appropriate, comments on the following:

a. Time injured person first seen by medical officer/representative.
b. Disposition of injured person; i.e. treated and retained aboard or transferred to another ship (military personnel) or transferred to a hospital for treatment (military and civilian personnel).
c. In cases of exposure to toxic fumes/chemical poisons, describe type of substance, concentration and type of exposure.
d. Describe additional causative/contributing factors not described in blocks 20 through 25 and indicate (D) for a definite cause, (S) for a suspected cause and (P) for condition present but not a factor. Enter name, rank/rate or grade and address of witnesses to the accident. If none, so indicate.

Block 18. Kind of Injury. Enter words from Block 18 (on reverse side of this sheet) which best describes nature of injury.

Block 19. Body Part Injured. Enter word(s) from block 19 (on reverse side of this sheet) which best describes body part affected by nature of injury

Block 20. Source of Injury. Enter object or environment from block 20 (on reverse side of this sheet) which best describes source of injury. (NOTE: A direct logical relationship between "Source of Injury" and "Kind of Injury" must be established).

Block 21. Kind of Accident. Enter action, motion or type of contact from block 21 (on reverse side of this sheet) which best describes means by which injured person came in contact with previously selected "Source of Injury". (NOTE: A direct logical relationship between the "Source of Injury" and "Kind of Accident" must be established.)

Block 22. Hazardous Condition. Enter the condition from Block 22 (on reverse side of this sheet) which best describes the hazardous condition which permitted or occasioned occurrence of previously selected "kind of Accident". (NOTE: A direct logical relationship between "Kind of Accident", "Hazardous Condition" and "Agency of Accident", which is to follow, must be established).

Block 23. Agency (and Agency Part) of Accident. Enter the object or environment from Block 20 (on reverse side of this sheet) which best describes the agency to which the hazardous condition applies. In addition, describe the part of the agency which is unsafe. For instance, if the agency is a table saw from which the blade guard has been removed, enter the words "cross cut saw - blade." In some agencies such as a length of pipe, rope, lumber, etc., no agency part is required to be named. The rule for agency part is - if corrective or preventive action for the part involved is different from the action on any other part of the agency, name the agency part involved. (NOTE: A direct logical relationship between "Hazardous Condition" and "Agency of Accident" must be established). If there is no hazardous condition there can be no agency or agency part of accident, and all three items shall be described as "Not Applicable"

Block 24. Unsafe Act. Enter the act or omission from Block 24 (on reverse side of this sheet) which best describes unsafe act which permitted or caused occurrence of previously named kind of accident. (NOTE: A direct logical relationship between "Unsafe Act" and "Kind of Accident" must be established).

Block 25. Unsafe Personal Factor. Enter the reason from Block 25 (on reverse side of this sheet) which best describes the unsafe personal factor which led to the "Unsafe Act" or contributed to the injury. (NOTE: If there was an unsafe act committed, an unsafe personal factor should always be selected. If no unsafe act was committed there may still, however, be an unsafe personal factor which contributed to the accident).

Block 26. Reason for Being on Government Property. Self-explanatory.

Block 27. Corrective Action Taken/Recommended. List specific remedial actions which have been or should be taken to prevent recurrence of similar injury. If an entry of "unknown" or "none" seems appropriate, an explanation shall be given as to why corrective action can not be recommended. Specify whether actions have been taken or are only recommended. If the latter, what action is expected?

Blocks 28 through 30. First Signature Line. Report is to be signed and dated by the individual who prepared the report to this point.

Block 31. Review and Comments of Safety Officer or Commanding Officer. Additional recommendations may be made if appropriate.

Blocks 32 through 34. Second Signature Line. Self-explanatory.

The remainder of the report form will only be filled out in those instances where the injury/death to the military member is reportable to JAG.

a. Blocks 1-34. Prepared in accordance with above instructions.
b. Blocks 4?-50. Self-explanatory.
c. Blocks 35 through 40, 42, and 44 through 46 shall be completed and signed by the medical officer on the basis of his observation or examination of the injured or deceased member and information then available to him.
d. Blocks 41, 43 and 47 through 50 shall be completed and signed by the commanding officer on the basis of his investigation (or by an officer authorized and directed by the commanding officer to investigate the incident and sign the report by direction).

29.52.3(127E)

Figure 2-8. —Instructions for Accidental Injury/Death Report (front).

BLOCK 18. KIND OF INJURY

AMPUTATION OR ENUCLEATION
ASPHYXIA, STRANGULATION
BURN OR SCALD (THERMAL)
BURN (CHEMICAL)
CAISSON DISEASE, BENDS
CONCUSSION, BRAIN
CONTUSION, CRUSHING, BRUISE
CUT, LACERATION, PUNCTURE, OPEN WOUND
DISLOCATION
DROWNING
ELECTRIC SHOCK, ELECTROCUTION
FOREIGN BODY LOOSE (DUST, RUST, SOOT)
FOREIGN BODY, RETAINED OR EMBEDDED
FRACTURE
FREEZING, FROSTBITE
HEARING LOSS, OR IMPAIRMENT
HEAT STROKE, SUNSTROKE, HEAT EXHAUSTION
HERNIA
*INJURIES, INTERNAL
*POISONING, SYSTEMIC
RADIATION, IONIZING
RADIATION, NONIONIZING
RADIATION, ACTINIC
SCRATCHES, ABRASIONS
SPRAINS, STRAINS
SUBMERSION, NONFATAL
*MULTIPLE INJURIES
UNDETERMINED
*OCCUPATIONAL DISEASE, NEC
*OTHER INJURY, NEC

BLOCK 19. BODY PART INJURED

*HEAD (INCLUDING FACE)
*NECK
*UPPER EXTREMITIES
*TRUNK
*LOWER EXTREMITIES
*MULTIPLE PARTS
*BODY SYSTEM
*BODY PARTS, NEC

BLOCKS 20 & 23. SOURCE OF INJURY AND AGENCY OF ACCIDENT

*AIR PRESSURE
*ANIMALS
*BODILY MOTION
*BOILERS, PRESSURE VESSELS - PARTS
*BOXES, BARRELS, CONTAINERS, PACKAGES (EMPTY OR FULL, EXCEPT GLASS)
*BUILDINGS & STRUCTURES - PARTS
*CHEMICALS & CHEMICAL COMPOUNDS
*CLOTHING, APPAREL, SHOES
*COAL AND PETROLEUM PRODUCTS
*CONSTRUCTION MATERIALS (NOT PART OF A STRUCTURE)
*CONVEYORS, GRAVITY OR POWERED (EXCEPT PLANT & INDUSTRIAL VEHICLES)
*DRUGS AND MEDICINES
*ELECTRIC & ELECTRONIC APPARATUS, NEC
*FLAME, FIRE, SMOKE
*FOREIGN BODIES OR UNIDENTIFIED ARTICLES
*FURNITURE, FIXTURES, FURNISHINGS
*GLASS & CERAMIC ITEMS, NEC
*HAND TOOLS (NOT POWERED; WHEN IN USE, CARRIED BY A PERSON)
*HAND TOOLS (MECH. & ELEC. MOTOR POWERED; IN USE, CARRIED AND HELD BY A PERSON)
*HEATING EQUIPMENT, NEC (NOT ELEC.) WHEN IN USE (FOR ELEC. FURNACES SEE ELECTRONIC APPARATUS)
*HOISTING APPARATUS
*ELEVATORS
*HUMAN BEING
*INSTRUMENTALITIES OF WAR
*MACHINES (PORTABLE & FIXED, EXCEPT WHEELED VEHICLES)
*METAL ITEMS, NEC
*MINERAL ITEMS, NEC
*NATURAL POISONS AND TOXIC AGENTS, NEC
NOISE
*PERSONNEL SUPPORTING SURFACES (DECK, LADDER, STAGE, BROW, PLATFORM)
*PLASTIC ITEMS, NEC
*PUMPS, ENGINES, TURBINES (NOT ELEC.)
*RADIATING SUBSTANCES AND EQUIPMENT (USE ONLY FOR RADIATION INJURIES)
*SCRAP, DEBRIS, WASTE MATERIAL, ETC., NEC (EXCEPT RADIOACTIVE)
*SHIP STRUCTURE - PARTS
*SPORTS
*TEMPERATURE (ATMOSPHERIC, ENVIRONMENTAL)
*TEXTILE ITEMS, NEC
*VEHICLES, (AIR, LAND, SEA) INCLUDING MILITARY AND INDUSTRIAL
WATER AND STEAM
*WOOD ITEMS, NEC
*MISCELLANEOUS, NEC
UNDETERMINED
*OTHER, NEC

BLOCK 21. KIND OF ACCIDENT

*STRUCK AGAINST
*STRUCK BY
*FALL OR JUMP FROM ELEVATION
*FALL OR JUMP ON SAME LEVEL
*CAUGHT IN, UNDER, OR BETWEEN
BITE OR STING, VENOMOUS AND NON-VENOMOUS
*RUBBED, ABRADED, PUNCTURED OR CUT
BODILY REACTION OR MOTION
*OVEREXERTION
*CONTACT WITH
UNDETERMINED
*OTHER, NEC

BLOCK 22. HAZARDOUS CONDITION

*DEFECT OF THE AGENCY OF ACCIDENT
*DRESS OR APPAREL HAZARD
*IMPROPER ILLUMINATION
*IMPROPER VENTILATION
*ENVIRONMENTAL HAZARD, NEC
*HAZARD OF OUTSIDE WORK ENVIRONMENT - OTHER
*INADEQUATELY GUARDED
*PLACEMENT HAZARD
*PUBLIC HAZARD
UNDETERMINED
NO HAZARDOUS CONDITION
*HAZARDOUS CONDITION, NEC

BLOCK 24. UNSAFE ACT

*WORKING ON MOVING OR DANGEROUS EQUIPMENT
*DRIVING ERRORS BY VEHICLE OPERATOR
*FAILURE TO USE PERSONAL PROTECTIVE EQUIPMENT
FAILURE TO WEAR SAFE PERSONAL ATTIRE
*FAILURE TO SECURE OR WARN
HORSEPLAY AND SKYLARKING
QUARRELING OR FIGHTING
*IMPROPER USE OF EQUIPMENT
*IMPROPER USE OF HANDS OR BODY PARTS
INATTENTION TO FOOTING OR SURROUNDINGS
*FAILURE TO USE SAFETY DEVICES
*OPERATING OR WORKING AT UNSAFE SPEED
*TAKING UNSAFE POSITION OR POSTURE
*UNSAFE PLACING, MIXING, COMBINING, ETC.
*USING UNSAFE EQUIPMENT
*OTHER UNSAFE ACTS, NEC
UNDETERMINED
NO UNSAFE ACT
NEC - NOT ELSEWHERE CLASSIFIED

BLOCK 25. UNSAFE PERSONAL FACTOR

UNDER INFLUENCE DRUG/ALCOHOL
FATIGUE
ILLNESS
*IMPROPER ATTITUDE
*LACK OF KNOWLEDGE OR SKILL
*BODILY DEFECTS
UNDETERMINED
NO UNSAFE PERSONAL FACTOR
*OTHER UNSAFE PERSONAL FACTOR, NEC

* SPECIFY/DETAIL

29.52.4(127E)

Figure 2-9.—Instructions for Accidental Injury/Death Report (back).

Utilitiesmen at certain grade levels who satisfactorily complete an applicable course of instruction at a Navy Class "C" school.

1. SHORE-BASED BOILER CONTROLS TECHNICIAN, UT-6102—He performs duties related to operating, maintaining and troubleshooting of the control systems of steam heating boilers, and high temperature hot water boilers and accessories to include: Automatic electrically controlled systems, manually controlled electric systems, automatic pneumatically controlled systems and control systems components; performs operational and combustion efficiency tests; adjusts controllers and linkages for fuel and air devices to obtain maximum operational efficiencies; uses mechanical and electrical test equipment to troubleshoot and balance automatically controlled systems; and sets up inspection and preventive maintenance programs.

This NEC is assigned only to personnel in paygrades E-5 through E-7 upon satisfactory completion of the applicable course of instruction. The applicable course is Utitilitiesman/Shore Based Boiler Controls. The course is offered by the Naval Schools Construction at Port Hueneme, California.

2. SHORE BASED REFRIGERATION AND AIR-CONDITIONING TECHNICIAN, UT-6104—He installs, operates, maintains, and performs organizational and/or intermediate level maintenance on refrigeration, air-conditioning, water cooling equipment, cube and flake ice machines, and block ice manufacturing plants.

This NEC is assigned only to personnel in paygrades E-5 through E-7 who satisfactorily complete the applicable course of instruction. The applicable course is Utilitiesman (Refrigeration Equipment Repair). It is offered at the U. S. Army Engineer School at Ft. Belvoir, Virginia.

3. PETROLEUM TANK FARM TECHNICIAN, UT-6117—He operates and maintains storage and transfer equipment for petroleum products at storage terminals and tank farms: Reserves and distributes petroleum by connecting available tanks; operates pump engines and valves to transfer petroleum; reads meters and gages to determine completion of petroleum transfer; verifies amount and type of petroleum in storage; operates fire fighting equipment, personnel protective and safety equipment common to petroleum storage facilities.

This NEC is assigned only to personnel in paygrades E-5 through E-7 who satisfactorily complete the applicable course of instruction. The applicable course is Petroleum Storage Specialist, which is given at the U. S. Army Quartermaster School at Ft. Lee, Virginia.

4. CONSTRUCTION PLANNER AND ESTIMATOR SPECIALIST, EA-5515—He plans and estimates material, manpower, and equipment requirements for various construction jobs: Performs scheduling, procurement, production control and management reporting of construction projects.

The NEC EA-5515 is assigned not only to UTs, but also to EAs, BUs, CEs, and SWs, in paygrades E-5 through E-7, who are graduates of the applicable course of instruction. The applicable course is Engineering Aids/Planning and Estimating. It is offered at the Naval Schools Construction at Port Hueneme, California.

5. ADVANCED UNDERWATER CONSTRUCTION TECHNICIAN, BU-5931—He performs underwater construction operations using all types of underwater equipment and tools: Plans and supervises simple underwater construction operations: estimates manpower and equipment requirements for various underwater construction projects; inspects material condition, monitors general readiness, diagnoses improper operating procedures and equipment casualties/failures.

The NEC BU-5931 is available to personnel in all Group VIII ratings, in paygrades E-5 through E-7, who are graduates of the applicable course of instruction which, at this writing, is under development. The course of instruction, when officially established, will be offered by the Naval Schools Construction at Port Hueneme, California.

6. BASIC UNDERWATER CONSTRUCTION TECHNICIAN, BU-5932—He performs underwater construction operations using common underwater tools, equipment, and materials: Performs duties related to underwater construction blasting; component emplacement and assembly; underwater cutting and welding; seafloor surveying; foundation and anchor emplacement; rigging; cable laying and splicing; and system testing.

The NEC BU-5932 is available to personnel in all Group VIII ratings, in paygrades E-5 through E-7, who are graduates of the applicable course of instruction which, at this writing, is under development. The course of instruction, when officially established, will be offered by the Naval Schools Construction at Port Hueneme, California.

7. SAFETY INSPECTOR, SW-6021—He organizes and supervises the operation of the

safety department: Investigates accidents and analyzes accidents and problem areas and recommends methods to decrease frequency and/or eliminate accidents; collects data to ascertain accident treads; inspects project sites, grounds, buildings and machinery to isolate hazards to life, health, and equipment; conducts safety education compaigns by preparing and/or distributing literature, posters, charts, and displays; organizes and directs safety committee; directs placement of traffic control signs and devices.

The NEC SW-6021 is assigned to personnel in all Group VIII ratings, in paygrades E-6 and E-7, who are graduates of the applicable course of instruction. The applicable course is Steelworkers/Safety Inspector, which is given at the Naval Schools Construction at Port Hueneme, California.

8. NUCLEAR POWER PLANT OPERATOR, 3391—He operates, maintains, and performs organizational level maintenance on nonpropulsive nuclear power plants and radioisotope power devices, as an Electrical, Mechanical, Instrument or Health Physics/Plant Chemistry Specialist.

NEC 3391 is normally assigned to personnel in paygrades E-4 through E-7 who are graduates of the applicable course of instruction. In addition to UTs, this NEC is also available to personnel in the following ratings: CE, EO, CM, SW, and HM. The applicable course of instruction is Nuclear Power Plant Operators. It is offered at the U. S. Naval Nuclear Power Unit at Fort Belvoir, Virginia.

CHAPTER 3

PLANS, SPECIFICATIONS, AND COLOR CODING

INTRODUCTION

In your day-to-day work as a Utilitiesman, you will be installing, assembling, inspecting, and troubleshooting various systems such as refrigeration, air conditioning, and plumbing. Your ability to effectively complete this work requires that you be able to read and correctly interpret all types of plans and drawings. You may also have for your use the applicable specifications that contain additional information on the details of construction and installation. For your safety, when working on these systems you will need to identify the safety hazards represented by the various color codes used on pipes and containers. All of these—plans specifications, and color coding—tie together to assist you in doing your job efficiently, correctly, and safely.

Careful study of the material in this chapter should result in your being able to read and interpret simple working drawings and sketches, and the more complex installation plans, using the applicable specifications to assist you in the details. In addition, you should be able to draw simple freehand sketches, convert between the English and metric systems of weights and measures, and specify the hazards associated with each colors used to code pipes and compressed gas containers.

PLANS

You will be working with several different types of plans and drawings, ranging from simple drawings and sketches made, perhaps, by your immediate supervisor to mechanical plans made by the draftsman using drawing instruments. The reproductions of the latter are the plans from which you will normally work.

MECHANICAL PLANS

Mechanical plans include layouts and details for systems of plumbing, heating, ventilating, air conditioning, and refrigeration. These systems may vary, depending on whether they are for a permanent installation with the most modern fixtures and equipment, or for a temporary installation where less complex equipment is used. Whatever the job entails, your task will be to correctly work from the plans so that the end result will comply with the plans.

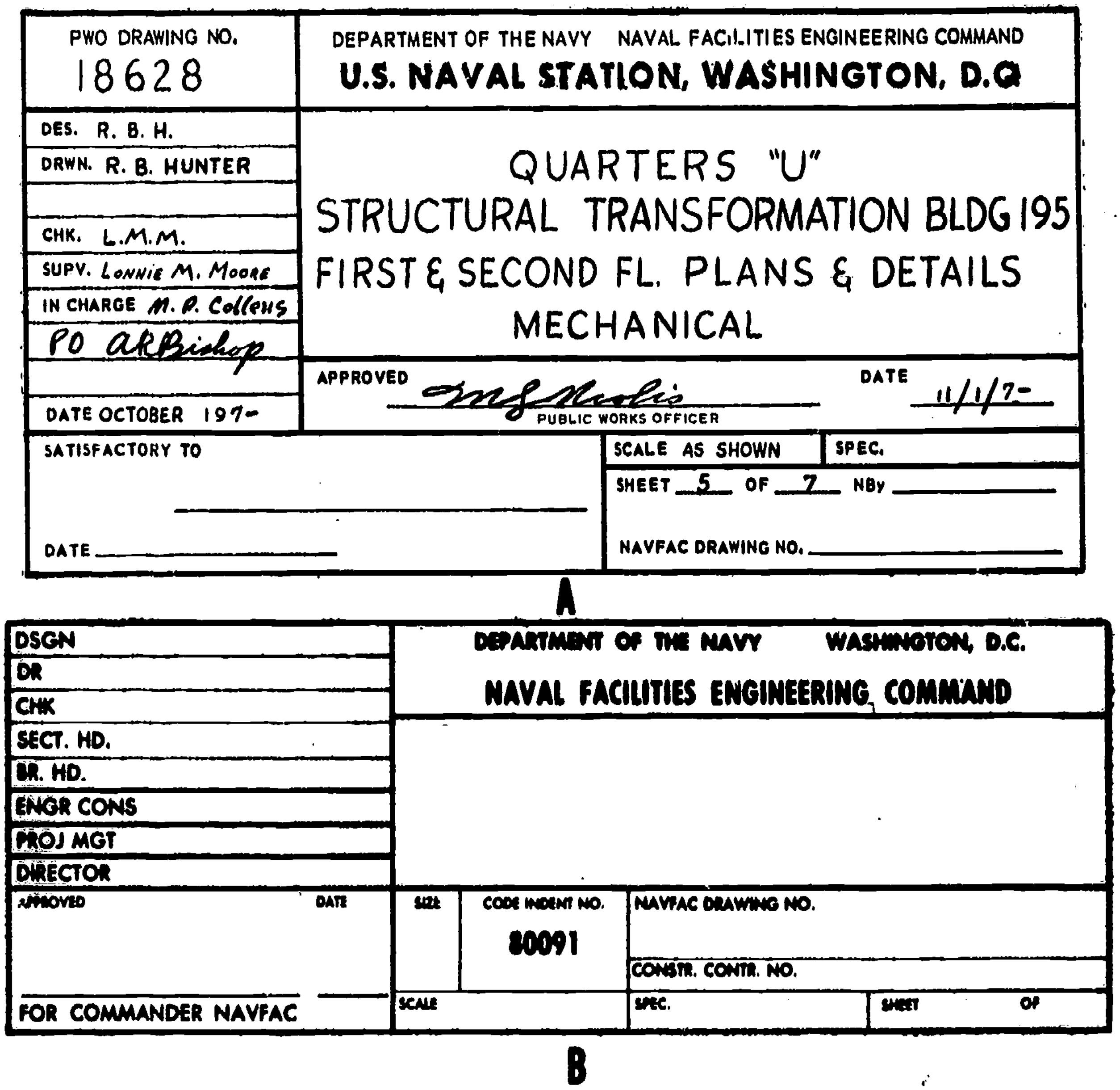
The chief parts of a mechanical plan are the views of the fixtures and equipment, and the layout and details of the system. In addition to these, plans contain certain additional written information. This information is contained in the title block, the bill of material, the scale, and the notes.

THE TITLE BLOCK

The title block is located in the lower right-hand corner of the drawing. A typical title block is shown in figure 3-1. The title block gives the title of the drawing and the number that has been assigned to that drawing. It also indicates who prepared the drawing, who checked it, the authority under which it was issued, the date approved, and other information such as the scale, specification numbers, and sheet number of multiple-sheet drawings.

BILL OF MATERIAL

The bill of material, sometimes called a material takeoff, is a grouped compilation based on takeoffs and estimates of all the materials needed to complete the installation. The bill of material for a given project is organized into a tabulated statement to include the item number of the parts and materials, their descriptions, the unit of measure, quantity, and stock number. A typical bill of material (fig. 3-2) shows that the item numbers in the first column refer to the drawing which makes it easier to identify each item, its location, and its purpose or function.



45.159

Figure 3-1. — Title Blocks.

In a Construction Battalion, a bill of material is prepared for a complete job or project and is referred to as the BM. This BM is prepared and maintained by the operations department and will list items under categories such as "used" "on hand," and so on. Check this BM from time to time during a job to make sure the materials needed are available.

When equipment assemblies are received at an overseas base, it is possible for you, by checking the bill of material, to determine quickly if the items shipped are what you need for the job at hand, and if they allow for changes made necessary by local conditions.

SCALE

You can understand the problem that would be involved if an architect or engineer, who plans a utilities system, endeavored to show it on paper according to actual size. To help you visualize the size and shape of the system, he reduces all dimensions to SCALE. Thus, on a drawing he may represent a foot by 1/2 inch, in which case a 40-foot run of pipe would be 20 inches in length.

BILL OF MATERIAL					
ITEM NO.	DESCRIPTION	UNIT	STOCK NUMBER	QUANTITY	
				TROP	NORTH
1	VALVE, ANGLE 1/2"	EA.	9C4820-541-0362	15	20
2	VALVE, CHECK 2"	EA.	Y4820-273-9902	5	12
3	BEND, WATER CLOSET	EA.	9C4730-278-8579	175	175
4	ELBOW, PIPE (90°) 1"	EA.	9C4730-249-3887	630	720
5	ELBOW, PIPE (45°) 1"	EA.	9C4730-221-4997	30	40
6	SINK, SERVICE	EA.	Y4510-260-1366	175	175
7	FAUCETS, DOUBLE (SWING SPOUT)	EA.	9C4510-253-0857	175	175
8	PIPE, COPPER 1/2"	FT.	9C4710-271-6101	1230	1150
9	VALVE, EXPANSION, AUTOMATIC	EA.	9C4820-271-4084	4	2
10	INSULATION TAPE, 1" THERMAL (ASBESTOS)	FT.	9C5640-158-8874	50	150
11	TRAPS, DRAINAGE PIPE, P-TYPE	EA.	9C4730-267-3082	180	200

65.10

Figure 3-2. — Bill of material.

The scale of a drawing is particularly important to the construction workers, but it also has a practical value to the Utilitiesman. Where piping is to be installed, for instance, the dimensions of pipes, and distances between them, will have to be considered in figuring the amount of piping required, and the number of fittings needed to join them.

Dimensions of an object should not be scaled or measured from a print when a very close measurement is necessary. These measurements frequently are inaccurate because of paper shrinkage from atmospheric conditions, drafting errors, and other such factors. To ensure accuracy, use the dimensions given on the drawing.

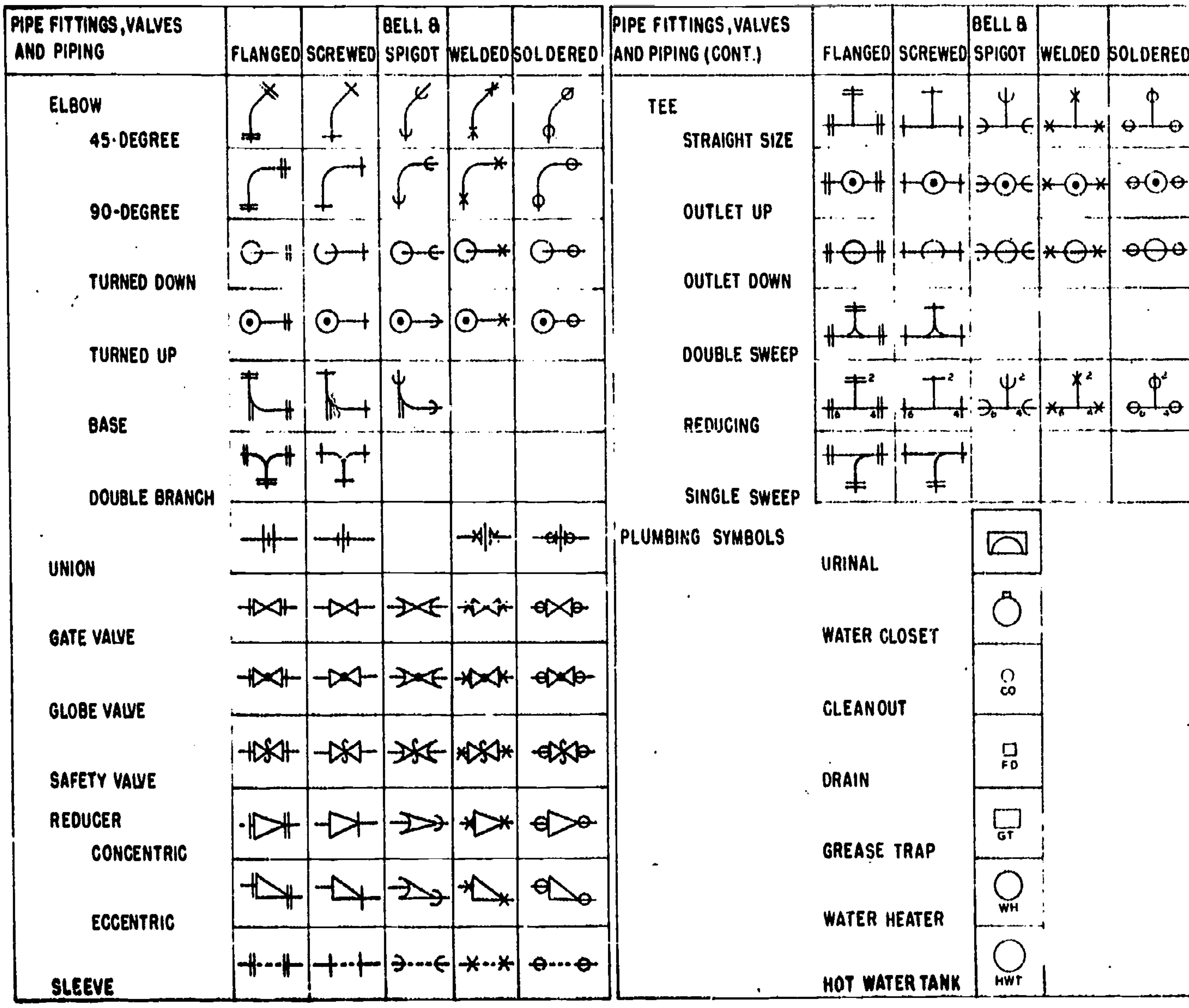
NOTES

Notes are written in such a manner that they are clear, explicit statements regarding material, construction, and finish. Notes also contain procedures for installation, and may contain explanations of particular parts of the drawing, and other types of pertinent information not included in the drawing. Remember that the notes must be read before beginning construction.

LINES AND SYMBOLS

Lines and symbols are used in the preparation of drawings, and each has a special meaning. To ensure that all lines and symbols used by the Armed Forces have the same special meaning to each person, they have been standardized. This standard is approved by the Department of Defense.

The latest military standard (Mil-Std) 17B-1, "Mechanical Symbols," was approved for use



11,330(54)

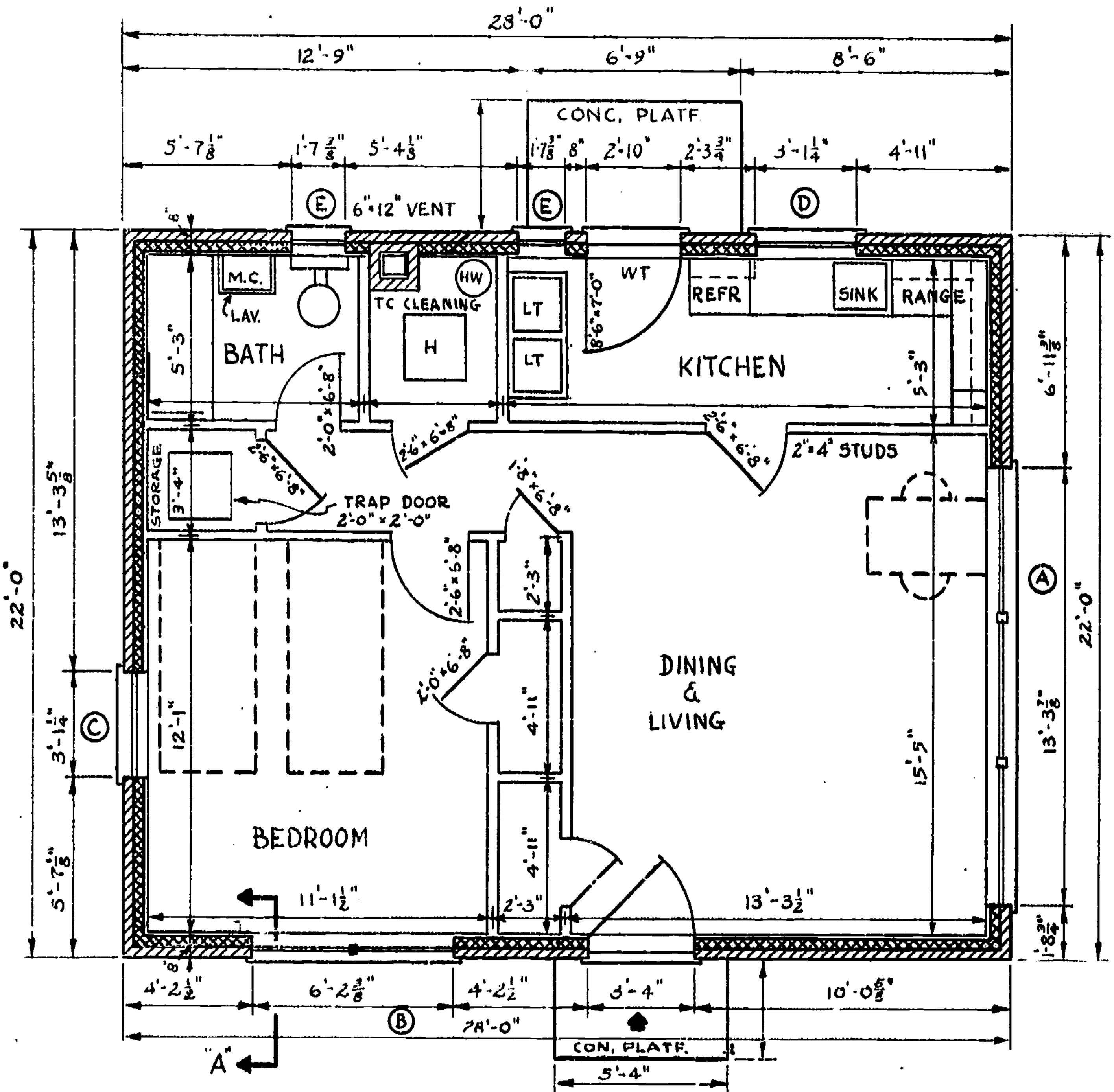
Figure 3-3. — Mechanical symbols.

23 Jan. 1963. This does not mean that revisions or changes to this Mil-Std will not be made in the future, nor that the plans now in use will be brought up-to-date by changes.

You must know how to interpret correctly both up-to-date and outmoded symbols to perform your job, both on new construction and on repair jobs. When performing construction work on a new job you will probably be using new plans. These drawings should have the latest approved lines and symbols. However, suppose you are attached to a Public Works shop where the base has been established 10 to 20 years or more. In this case you will be required to perform maintenance and repairs by referring to older plans which will contain outmoded symbols and line designators.

Figure 3-3 shows some of the more common mechanical symbols extracted from Mil-Std-17B-1. The older symbols will be generally similar, so if you can identify the new ones you should not have any trouble understanding the older ones that you may encounter.

Only a brief introduction to reading and interpreting plans has been presented here. To fully qualify for UT 3 & 2, you should study chapters 1, 2, 7, 8, and 10 of Blueprint Reading and Sketching, NavPers 10077-C.



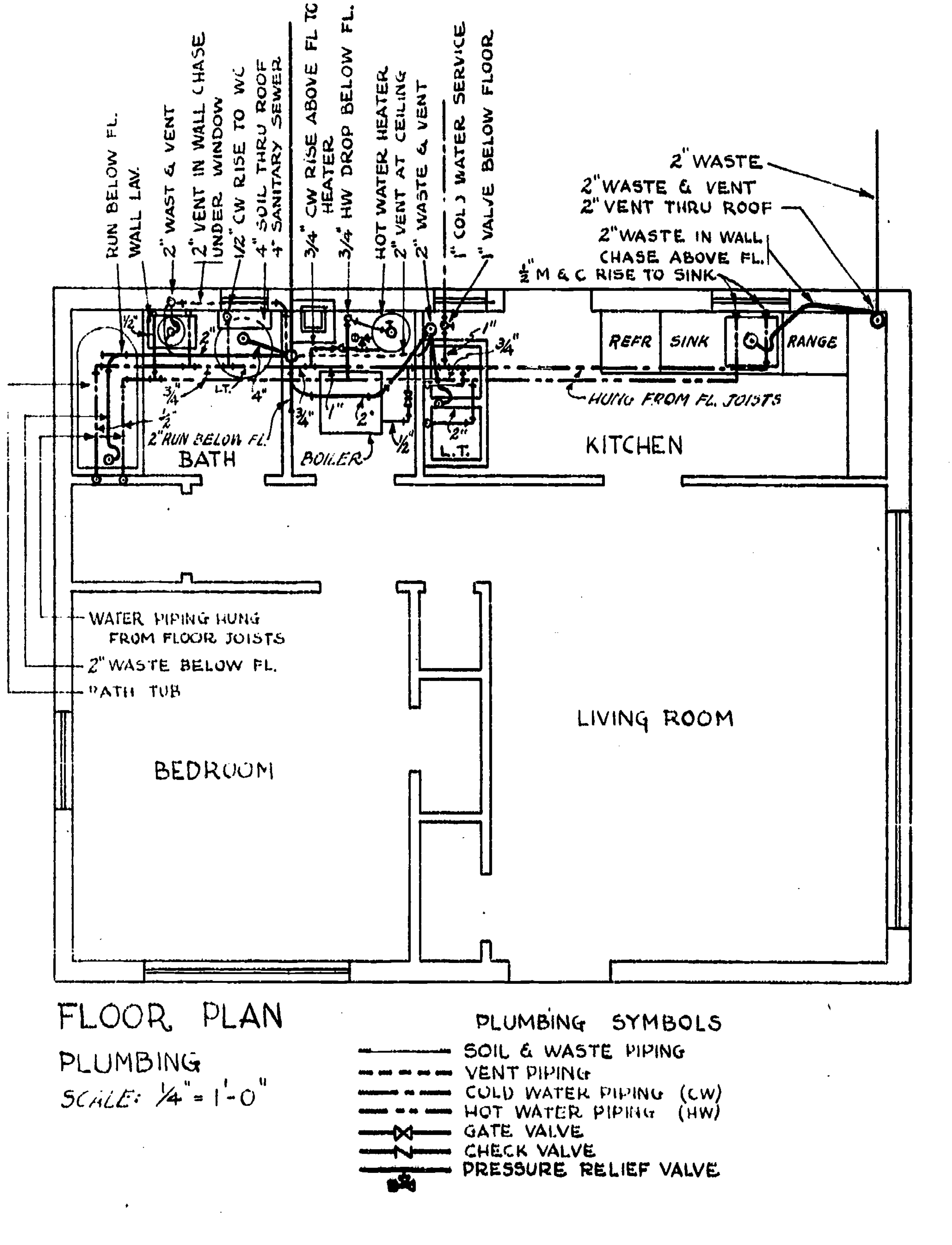
FLOOR PLAN
SCALE 1/4" = 1'-0"

SPECIFICATIONS

Although the plans that you will be working from will usually have sufficient detail, there will be times when you will need additional information regarding materials and methods of work to be used. This information may be found in the appropriate specification: Plans and specifications go together to provide all the visual and written information about a project required by you as the constructor, installer, or maintainer.

There are several types of specifications (commonly called SPECS) but you will work primarily with Federal, Military, NavFac, and project guide specifications.

Project guide specifications usually begin with Division 1, the GENERAL REQUIREMENTS for



45.515(54)

Figure 3-4. — Typical plumbing layout for a small house.

the structure, stating type of foundation, character of load-bearing members (wood-frame, steel-frame, concrete), type or types of doors and windows, types of mechanical and electrical installations, and the principal function of the building.

1. Next come the SPECIFIC CONDITIONS which must be carried out by the constructors. These are grouped in divisions under headings applying to each major phase of construction, as in the following typical list of divisions:

2. -SITE WORK 3. -CONCRETE 4. -MASONRY 5. -METALS 6. -CARPENTRY 7. -MOISTURE CONTROL 8. -DOORS, WINDOWS, AND GLASS 9. -FINISHES 10. -SPECIALITIES 11. -EQUIPMENT 12. -FURNISHINGS 13. -SPECIAL CONSTRUCTION 14. -CONVEYING SYSTEMS 15. -MECHANICAL and 16. -ELECTRICAL.

Sections under one of these general categories generally begin with GENERAL REQUIREMENTS for that category, and continue with the specific requirements. An example of a section of Division 15 follows.

In studying the guide specifications for plumbing which follow, study the drawing shown in figure 3-4, keeping in mind that these specifications are for this particular project and are listed as samples.

DIVISION 15- MECHANICAL

Section 15. 1a- Plumbing

15. 1a-01. GENERAL REQUIREMENTS. — The work consists of a complete plumbing system including the sanitary soil, waster, and vent piping; cold and hot water supply piping, water meter (if required), plumbing fixtures, hot water heater, and other necessary appurtenances. The system shall be inspected, tested, and approved by local governing plumbing codes before burying, concealing, or covering the various piping systems. Each system shall be complete and ready for operation except as specified or indicated otherwise.

15.1a-02. SANITARY SEWER, below ground level, shall be of extra heavy cast iron soil piping and fittings of the bell-and-spiget type, extending 3 to 5 feet beyond the foundation wall and graded not less than 1/8 inch per foot. The joint shall be made from a good grade of twisted oakum uniformly and well tamped into the joint and with a 1-inch depth of hot poured lead, made in one pouring, and caulked tight. All horizontal soil connections to the system shall be accomplished by Y-fittings or combination Y-and-1/8 bends and all changes in direction greater than 1/8-bends shall be of the long sweep pattern. Lines shall be well supported to eliminate sagging. Backfilling shall be well tamped in 6-inch layers.

15. 1a-03. SANITARY SEWER, ABOVE GROUND, shall be as specified for below ground, except wastelines and vent piping above ground shall be of zinc coated, standard-weight, screwed-end steel pipe and cast iron, recessed, long radius, screwed drainage fittings, graded not less than 1/8 inch per foot. The sanitary sewer vent shall extend full size through the roof for a distance of not less than 12 inches, where it shall be flashed with suitable corrosion resistant metal before the roofing is installed. A 4-inch cleanout shall be provided just above ground elevation at the base of the soil stack. All male screw ends shall be coated with a good grade pipe joint compound before entering into fittings. The bath tub trap shall be provided with a 3/4-inch, brass, screw drain plug; all lines shall be properly supported from the floor joists with suitable hangers. Closet-bowl floor connection shall have a cast iron closet-bowl floor flange with provisions for anchoring the brass closet-bowl bolts and an approved type of horn gasket. The finished joint shall be absolutely leak-proof and the bowl shall sit squarely on the finished floor.

15. 1a-04. WATER PIPING BURIED IN THE GROUND shall be jointless, type K, soft copper tubing. No kinking of the tube will be allowed.

15. 1a-05. WATER PIPING ABOVE GROUND shall be type "L," hard copper tubing with solder types of fittings except that vertical lines may be of type "L," soft copper tubing. All tubing lines shall be properly anchored to the floor joists to eliminate pipe sag and vibration, and pitched to the main shutoff valve for draining when necessary. A hose bibb shall be provided at the rear of the building with a stop and waste located inside the foundation wall for winter cutoff and waste, and arranged for complete drainage of the line from the hose bibb. Slip joint connections will not be permitted below finished floor.

15. 1a-06. Fixtures shall be of a reliable manufacturer and shall be as follows:

(a) KITCHEN SINKS shall have a left hand drainboard and be of cast iron with a smooth, white, acid-resisting porcelain enamel finish, 54 inches long by 25 inches wide by 36 inches from floor to top of rim. The trim shall be chromimum plated, including combination mixing faucets with soapdish, large basket-type strainer with 1 1/2-inch tail piece, and a 1 1/2-inch, wall-type P-trap. Hot and cold water supply lines in the sink cabinet shall be provided with copper tubing valves. The cabinet shall be of a heavy gage steel with a baked-on, white enamel finish and have at least two sliding drawers.

15. 1a-07. WATER HEATER shall be of the electrical storage type with a capacity of not less than 52 gallons. It shall be of an approved manufacturer with the underwriter's label attached. It shall be provided with two thermostatically operated heating elements; a 1500-watt element located near the top and a 1000-watt element located near the bottom of the tank. A 3/4-inch, bronze, drain valve shall be provided at the extreme bottom of the tank, with a 3/4-inch hose connection. A 1/2-inch, brass, combination temperature and pressure relief valve with a discharge extending to floor drain shall be furnished. A copper tubing valve shall be installed in the cold water supply. Electrical work shall conform to the local governing electrical codes.

15. 1a-08. A main shutoff valve shall be installed as indicated or specified. The 1-inch, main shutoff valve shall be accessible, of the stop and waste pattern with soldering type ends and the waste arranged for complete drainage of the entire water supply system.

15. 1a-09. WORKMANSHIP shall be performed in a first class manner, observing all standards of good installation practices.

(b) LAUNDRY TRAY shall be of the double-compartment, cement type, 48 inches long by 20 inches wide by 32 inches high from floor to rim and be of a smooth cement mixture to withstand sudden temperature changes without cracking or leaking. Tubs shall have a metal guard around their rims. The laundry tray shall be complete with stand, combination mixing faucets with tray mounting brackets, 1 1/2-inch tail pieces, and 1 1/2-inch wall type P-trap. A copper tubing valve shall be provided in each supply line.

(c) WATER CLOSET shall be of white, vitreous china, close-coupled tank and bowl, complete with white seat and seat cover, and have a chromium, 3/8-inch, screwed, brass, floor supply line with a chromium I. P. valve.

(d) LAVATORY shall be cast iron with a white porcelain enameled finish. The trim shall be chromium plated and shall include combination mixing faucets with a 1 1/4-inch tail-piece, pop-up waste, 1 1/4-inch wall trap, and 3/8-inch, screwed, brass floor supplies with I. P. valves.

(e) Tub shall be built-in type, cast iron, with a white porcelain enameled finish. The trim shall be chromium plated and include a built-in wall-type faucet complete with shower attachments, a curtain rod and pins and a 1 1/2-inch, trip-lever waste. Copper tubing valves shall be provided on each supply inside the wall access door.

15. 1a-10. TESTS shall be conducted on all plumbing systems to provide tightness of all piping joints. If leaks occur, they shall be repaired immediately and the tests repeated. The soil, waste, and vent systems shall be completely filled with water to the highest point before checking for leaks. The hot and cold water piping shall be tested with water at one and a half times the working pressure. After all tests have been proven satisfactory, all necessary adjustments on the faucets, traps, valves, and other specialties shall be checked in order that the entire system can be placed in normal operation.

15. 1a-11. INSULATION.—All piping and fittings subjected to freezing temperatures shall be adequately insulated with a suitable frostproof covering well secured in place.

The project guide specifications, then, provide all the normally required information on the materials and methods of work to be used in completing a project that is not contained in the plans. There may be times when you will need to know more about the characteristics of materials listed in the bill of materials. For example, if you cannot obtain a specified type of material or piece of equipment and want to substitute, you will need to know the characteristics of each in order to compare before making the decision to substitute. This is where a knowledge of and access to Federal, Military, and NavFac specifications are important.

FEDERAL specifications are written technical descriptions of materials and supplies used by the Navy and other Federal government departments. They cover in detail the characteristics and compositions of these items, and are listed, along with Military specifications, in numerical and alphabetical indexes generally available to you.

MILITARY specifications are similar to Federal specifications but are developed for use by the Department of Defense. Formerly called JAN (Joint Army and Navy) specifications, they are

Table 3-1. —Selected Values of Mechanical Units in the English Systems of Measurement

TYPE OF MECHANICAL UNIT	SELECTED VALUES
LENGTH	12 inches (in.) = 1 foot (ft) 3 ft = 1 yard (yd) 5280 ft = 1 mile (mi) 1760 yd = 1 mi
AREA	144 square inches (sq in. or $in.^2$) = 1 square foot (sq ft or ft^2) 9 ft^2 = 1 yd^2
VOLUME	1728 cubic inches (cu in. or $in.^3$) = 1 cubic foot (cu ft or ft^3) 27 ft^3 = 1 yd^3
FORCE (WEIGHT)	16 ounces (oz) = 1 pound (lb) 2000 lb = 1 ton

147.185

being revised to MIL-SPECS using the same serial number as before.

The last of the specifications that you will most likely use at one time or another are the NavFac specifications. These are developed by the Naval Facilities Engineering Command and cover the Naval Facilities Engineering Command and cover those items normally used for construction. They are listed as "Y" and Standard specifications in the Specifications Used in Contracts for Public Works manual, NavFac P-34.

FREEHAND SKETCHING

There may be times when subordinates and fellow workers do not understand a part of a plan to be used in their work. To help explain the work, it may be advantageous for you to make a freehand sketch of the confusing part of the plan. The freehand sketch is a rough outline of the confusing part of the plan and usually contains the angles, dimensions, and details required to make the sketch clear to the user. Sketches also can perform, partially, the duties of remote supervision by providing all the information that you, as a crew leader would provide if you were present, thereby allowing you to attend to other important duties. In addition, there may be times when you want to explain a new idea to your supervisor and find that a visual presentation in the form of a freehand sketch will help you sell the idea.

For all of these reasons, plus the requirement of the Manual of Qualifications for Advancement, you must be able to make freehand sketches. Chapter 3 of Blueprint Reading and Sketching, NavPers 10077-C, contains all the information required for you to be able to make freehand sketches. Study of this chapter and practice will ensure that you can meet the qualification when this skill is required.

SYSTEMS OF WEIGHTS AND MEASURES

There are two major systems of weights and measures used in the world today—the English

Table 3-2. — Selected Values of Mechanical Units in the Metric Systems of Measurement

TYPE OF MECHANICAL UNIT	SELECTED VALUES
LENGTH	10 millimeters (mm) = 1 centimeter (cm) 10 cm = 1 decimeter (dm) 10 dm = 1 meter (m) 100 cm = 1 meter 1000 mm = 1 meter 10 m = 1 dekameter (dkm) 100 m = 1 hectometer (hm) 1000 m = 1 kilometer (km)
AREA	100 square millimeters (mm^2) = 1 cm^2 100 cm^2 = 1 dm^2 100 dm^2 = 1 m^2
VOLUME	1000 cubic millimeters (mm^3) = 1 cm^3 1000 cm^3 = 1 dm^3 1000 dm^3 = 1 m^3
	1 milliliter (ml) = 1 cm^3 1000 ml = 1 liter (l) 100 centiliters (cl) = 1 liter 10 deciliters (dl) = 1 liter
FORCE (WEIGHT)	1000 milligrams (mg) = 1 gram (g) 100 centigrams (cg) = 1 gram 1000 grams = 1 kilogram (kg)

147.186

and metric systems. In the English system, the units of length are the inch, foot, yard, and mile; the units of area are the square inch, square foot, square yard, and square mile; the units of volume are the cubic inch, cubic foot, cubic yard, and, sometimes, the cubic mile; and the units of force (weight) are the ounce, pound, and ton. You probably learned in elementary school how to convert from one unit to another. If you need to refresh your memory on some of these relationships, refer to table 3-1.

Table 3-2 shows the metric system units of measurement. The basic unit for length is the meter, for area the square meter, for volume either the cubic meter or liter, and for force (weight) the gram. For measuring values substantially greater or smaller than the unit, prefixes are used. The same prefixes are used for all units. Table 3-3 lists these prefixes with their relationship to the basic unit. For example, a kilogram is 1,000 grams and a milligram is one-one thousandth of a gram; a kilometer is 1,000 meters and a millimeter is one-one thousandth of a meter.

As a Utilitiesman Third Class or Second Class, your job, someday, might involve conversion from one system to the other. It seems likely that in the future the United States will

Table 3-3.—Metric System Prefixes and Their Conversion Factors Used for Length and Force

METRIC SYSTEM PREFIXES	MULTIPLIERS Converting FROM the Basic Unit	Converting TO the Basic Unit
DEKA- or DECA	.1	10
HECTO-	.01	100
KILO-	.001	1000
MEGA-	.000001	1000000
DECI-	10	.1
CENTI-	100	.01
MILLI-	1000	.001
MICRO-	1000000	.000001

147.184

change from the English system to the metric system and, for a time, this will entail daily conversions to the metric system.

Table 3-4 gives the equivalents in each system. An easy way for you to get on board in this conversion is to remember only the conversion factors for one unit in each system for each category. For example, you might use the inch, square inch, cubic inch, and ounce as the units that you will memorize. Then a yard becomes 36 inches (table 3-1), a square foot becomes 144 square inches, a cubic foot becomes 1,728 cubic inches, and a ton becomes 32,000 ounces (2,000 pounds times 16 ounces).

Table 3-4 will help you convert from the basic units of the English system to the basic units of the metric system. For example, 1 inch = .0254 meters, 1 square inch = .000645 square meters, 1 cubic inch = .00001639 square meters, and 1 ounce = 28.3495 grams. The following examples show how the conversion is computed:

Problem 1:
Convert 2.5 feet to meters
2.5 feet = 30 inches
30 inches times .0254 (number of meters in an inch) = .762 meters

Table 3-4.—Selected English-Metric and Metric-English Conversions

TYPE OF MECHANICAL UNIT	ENGLISH-METRIC CONVERSIONS	METRIC-ENGLISH CONVERSIONS
LENGTH	1 inch = .0254 meter	1 meter = 39.37 inches
AREA	1 in.^{2} = .000645 m^2	1 m^2 = 1549.9 in.^{2}
VOLUME	1 in.^{3} = .00001639 m^3	1 m^3 = 61,023 in.^{3} 1,000 cm^3 = 1 liter
WEIGHT	1 ounce = 28.3495 grams	1 gram = .03527 ounces

147.187

Table 3-5.—Warning Colors

Class	Standard Color	Class of Material
a	Yellow, No. 13655	FLAMMABLE MATERIALS. All materials known ordinarily as flammables or combustibles. Of the chromatic colors, yellow has the highest coefficient of reflection under white light and can be recognized under the poorest conditions of illumination.
b	Brown, No. 10080	TOXIC AND POISONOUS MATERIALS. All materials extremely hazardous to life or health under normal conditions as toxics or poisons.
c	Blue, No. 15102	ANESTHETICS AND HARMFUL MATERIALS. All materials productive of anesthetic vapors and all liquid chemicals and compounds hazardous to life and property but not normally productive of dangerous quantities of fumes or vapors.
d	Green, No. 14260	OXIDIZING MATERIALS. All materials which readily furnish oxygen for combustion and fire producers which react explosively or with the evolution of heat in contact with many other materials.
e	Gray, No. 16187	PHYSICALLY DANGEROUS MATERIALS. All materials not dangerous in themselves, which are asphyxiating in confined areas or which are generally handled in a dangerous physical state of pressure or temperature.
f	Red, No. 11105	FIRE PROTECTION MATERIALS. All materials provided in piping systems or in compressed-gas cylinders exclusively for use in fire protection.

54.305

Problem 2:
Convert 4 square feet to square meters
4 square feet = 576 square inches (4 x 144)
576 square inches times .000645 (number of square meters in one square inch) = .37152 square meters

Problem 3:
Convert 2 tons to grams
2 tons = 4,000 pounds (2 x 2,000)
4,000 pounds = 64,000 ounces (4,000 x 16)
64,000 ounces times 23.3495 (number of grams in an ounce) = 1,722,368 grams

By studying tables 3-1 and 3-4, you will soon be able to convert from any unit in the English system to a unit in the metric system.

Often the number you will arrive at in the metric system will be difficult to work with and this is where the use of the prefixes becomes practical. By referring to table 3-3, you can see that you can go from the basic unit (in length and force only) to a unit with a prefix by using the multiplier in the FROM column. In problem 3, the answer was 1,722,368 grams, an unhandy number. To convert from this basic unit, we might follow the table and multiply by .1 to get 172,236.8 dekagrams, by .01 to get 17,223.68 hectograms, by .001 to get 1,722.368 kilograms, or by .000001 to get 1.722368 megagrams, (which probably would be rounded off to 1.7 megagrams) a handier number.

When working with AREA and VOLUME, however, the multiplier for AREA must be

Table 3-6. —Size of Stencil Letters

Outside diameter of pipe or covering	Size of Stencil Letters
Inches	Inches
Under 1 1/2	1/2
1 1/2 to 3 1/2	3/4
3 1/2 to 6	1 1/4
6 to 9	2
9 to 13	3
Over 13	3 1/2

54.306

squared before use and the multiplier for VOLUME must be cubed. That is, if the multiplier is 10 for area, 100 (10 x 10) must be used; if the multiplier for volume is .1, .001 (.1 x .1 x .1) must be used. Remember, for length and force, use the multiplier as is; for area and volume, square and cube the multipliers respectively before use.

If a measurement can be converted from the English system to the metric system, logically, a measurement in the metric system can be converted to the English system. This will be the case when new manuals (written in the metric system) will be supplied to users who have old equipment (still based on the English system). This conversion is still a 3 step process; (1) conversion to the basic unit, (2) conversion to the English equivalent, and (3) conversion to a handy English unit.

To perform step one, use the column headed "Converting TO the Basic Unit" in table 3-3. As an example, 75 centimeters is multiplied by .01 to get an equivalent in the basic unit of .75 meters. As another example, 2 kilograms is multiplied by 1,000 to get an equivalent in the basic unit of 2,000 grams.

The second step involves the use of table 3-4. This shows that 1 meter = 39.37 inches, 1 square meter = 1549.9 square inches, 1 cubic meter = 61023 cubic inches, and 1 gram = .03527 ounce. The following examples show how this step is performed:

Problem 1:
Convert .2 meter into inches
.2 meters times 39.37 (number of inches in 1 meter) = 7.874 inches

Problem 2:
Convert 25 cubic centimeters into cubic inches
25 cubic centimeters = 25 x .01 x .01 x .01 = .000025 cubic meters
.000025 cubic meters times 61,023 (number of cubic inches in one cubic meter) = 1.525 cubic inches

Step 3 is to use table 3-1 to convert to a handier unit, i.e., inches to feet, yards, or miles. In both problems 1 and 2, you would probably leave the answer as is, but in other problems, you may decide to convert the answer to feet, yards, cubic yards, or tons, as appropriate, to obtain a number handier to work with.

COLORS FOR SAFETY

Color warnings provide an effective means for marking physical hazards, for indicating the location of safety equipment, and for identifying fire and other protective equipment. As a Utilitiesman, you may often be concerned with uniform colors used for marking pipelines carrying hazardous materials, compressed-gas cylinders and fire protection equipment.

CLASSES OF MATERIALS AND THEIR COLOR CODES

Five classes of material have been selected to represent the general hazards for all dangerous materials, while a sixth class has been reserved for fire protection materials. A standard color has been chosen to represent each of these classes, as indicated in table 3-5.

In some instances, piping systems which do not require warning colors may be painted to match surroundings; in other instances, such systems may be painted aluminum, black, or remain unpainted.

MARKING PIPING SYSTEMS

In addition to color warnings, WRITTEN TITLES should be used to identify hazardous or dangerous materials conveyed in piping systems.

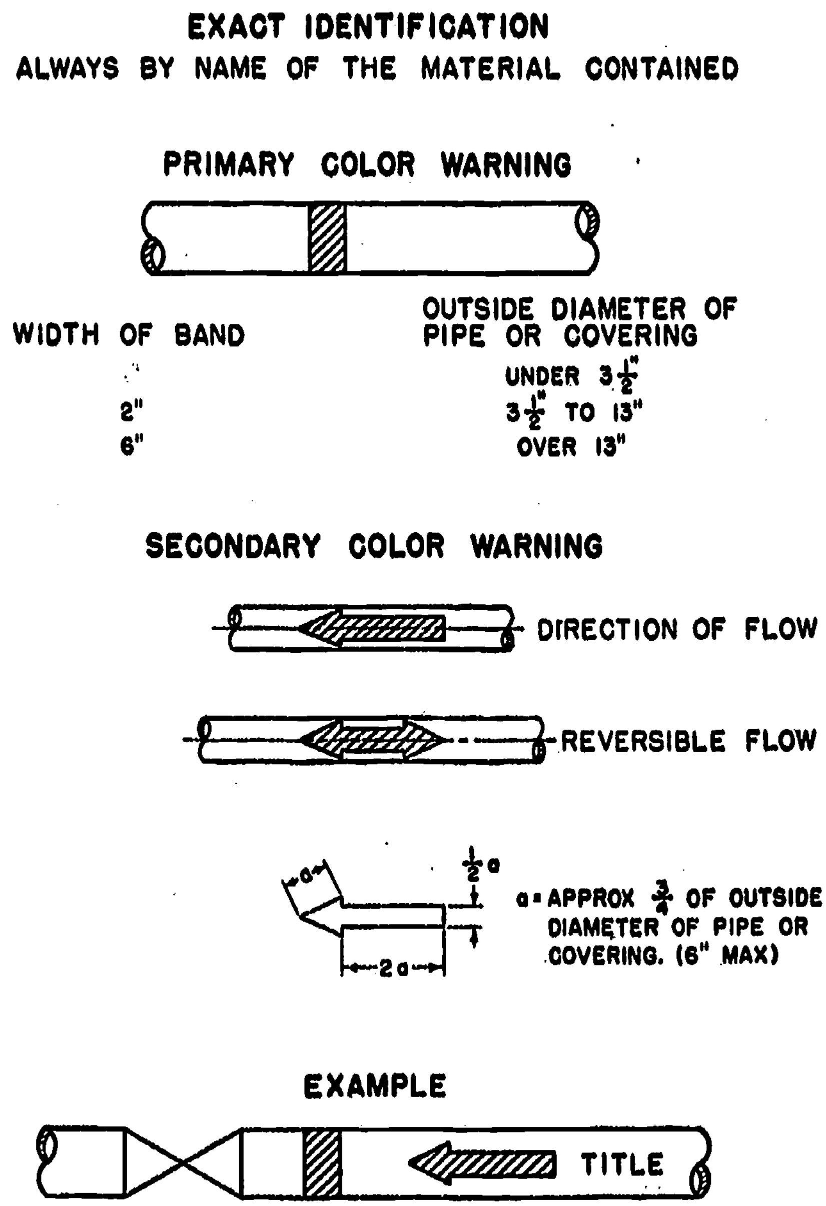


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Figure 3-5.—Identification of piping system.

Titles should be stenciled or lettered on pipe (or covering) where the view is unobstructed, such as on the lower quarters. Lettering in this position is unlikely to be obscured by dust collection or mechanical damage. Titles should be in black or white ONLY, and be clearly visible from operating position, especially those adjacent to control valves.

The use of stencils with standard size letters, as specified in table 3-6, is recommended. For pipelines smaller than 3/4 inch in diameter the use of securely fastened metal tags, with lettering etched or filled in with enamel, is suggested. It is recommended that titles be applied by use of upper case letters and Arabic numerals whenever applicable.

PRIMARY COLOR WARNINGS should be a single color, applied as a BAND (or BANDS), which completely encircles the piping system, and is located on the piping system immediately adjacent to all operating accessories such as valves, regulators, strainers, and vents. The bands will be painted throughout the system at convenient intervals, where branch lines join the system, where the system passes underground or through walls, and at any other conspicuous place where warnings are required.

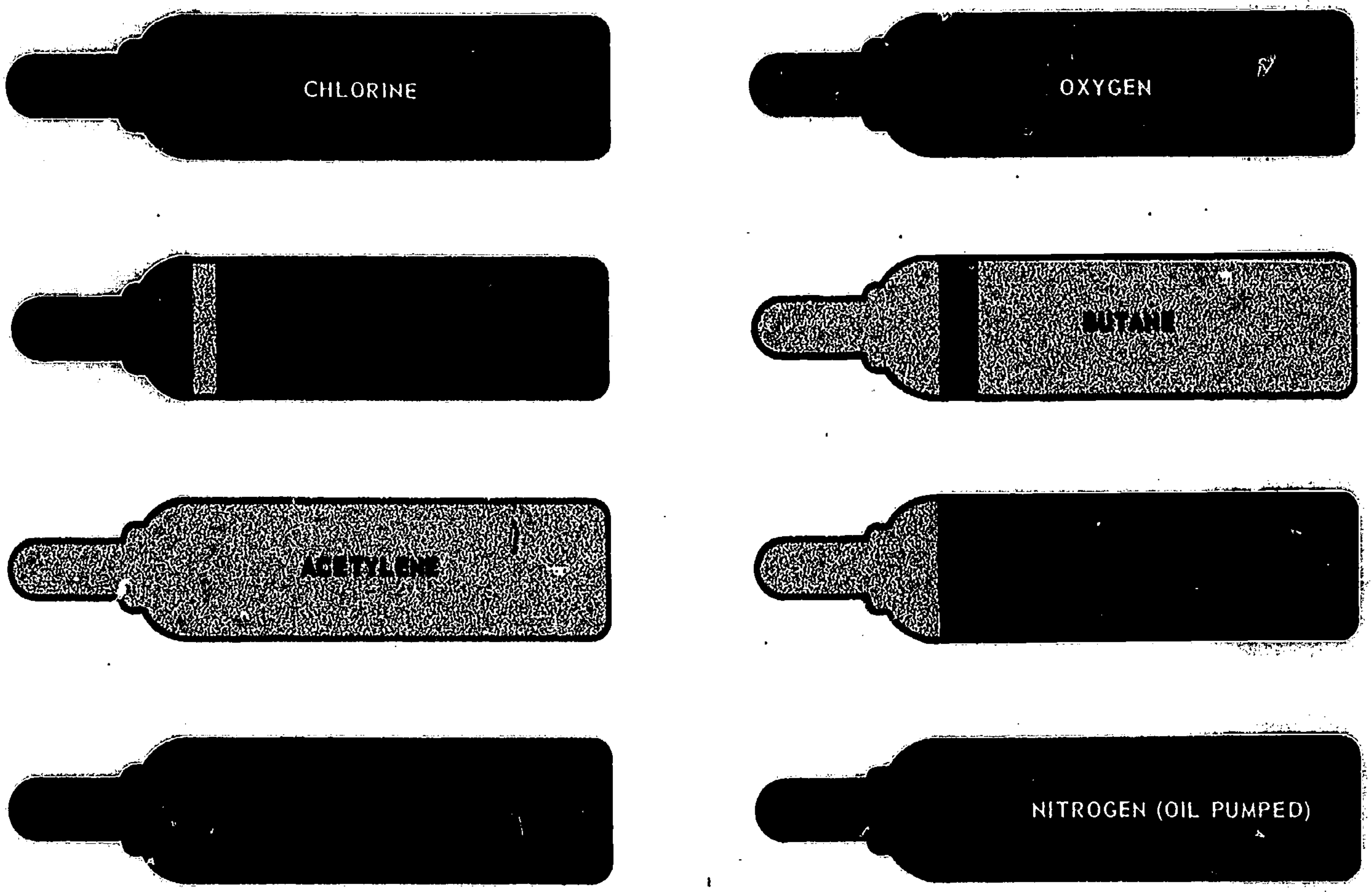

Figure 3-6.—Compressed gas cylinders commonly used by Utilitiesman.

All piping and covering of an entire system excluding straps, hangers, and supports may be painted with the primary color warning. When this is done, DO NOT paint color bands of any kind on the system.

A colored ARROW should be used adjacent to each primary color warning applied to a piping system, and will indicate the normal direction of flow of the material in the system. A double headed arrow is to be used on lines subject to reverse flow. Color of arrows can be the same as the primary warning, when bands are used, or black or white. (Refer to fig. 3-5 or exact identification of piping systems.)

MARKING COMPRESSED-GAS CYLINDERS

Compressed-gas cylinders used throughout the Department of Defense are of a standard color code. Exact identification of the material contained within is indicated by a written title, appearing in two locations diametrically opposite and parallel to the longitudinal axis of the cylinder. Cylinders having a background color of yellow, orange, or buff will have the title painted black. Cylinders having a background color of red, brown, black, blue, gray or green will have the title painted white.

A primary color warning is the color assigned to the class of material into which a material is classified in accordance with its primary hazard from the safety standpoint. These colors appear as a circular band on piping systems, and as main body, top, or band colors on compressed-gas cylinders.

A secondary color warning is the color assigned as a warning of a secondary hazard possessed by a material having a type of hazard distinctly different from that indicated by its primary color warning. These colors appear as arrows (or triangles) on piping systems and as main body, top, or band colors on compressed-gas cylinders.

Two decalcomanias may be applied on the shoulder of each cylinder diametrically opposite at right angles to the titles. They should indicate the name of the gas, precautions for handling, and use. A background color corresponding to the primary color warning of the contents should be used.

Shatterproof cylinders must be stenciled with the phrase "Non-Shat" longitudinally 90° from titles. Letters must be black or white and approximately 1 inch in size.

On cylinders owned by or procured for the Department of Defense, the bottom and the lower portion of the cylinder body opposite the valve end may be used for Service ownership titles.

The appearance on the body, top, or as a band of any of the six colors in table 3-5 will provide a warning of danger from the hazards involved in handling the type of material contained in the cylinder.

Figure 3-6 shows cylinders most commonly found in a Construction Battalion or in a Public Works Department where Seabee personnel will be working. For a complete listing of compressed-gas cylinders refer to MIL-STD 101A; but, in so doing make sure you have a standard with the latest up-to-date changes inserted, as changes may occur in the manual as prescribed by the Department of Defense after this writing.

CHAPTER 4

PLUMBING

One of the principal duties of the Utilitiesman in the Navy is PLUMBING. Plumbing includes the installation, maintenance, and repair of piping, fixtures, and appliances used at shore activities for the collection of sanitary sewage, storm water, and other wastes, and for the distribution of water, gas, compressed air, fuels, lubricants, and other fluids.

To become a good plumber, you will have to acquire a lot of information on piping materials, fittings, tools, and methods and procedures used in plumbing work. You will also need a lengthy period of on-the-job training under a good supervisor or instructor so that you will be able to develop skill in using the tools of this trade, as well as to acquire efficiency in carrying out a job according to the methods and procedures considered as standard practice in plumbing.

This chapter deals primarily with such topics as pipe materials, fittings, fixtures and various duties having to do with the installation of a plumbing system. Instruction is provided on two major phases of plumbing: sewer systems and water service. The chapter also contains information on low-pressure compressed air systems. The following chapter deals with repairs and adjustments which you may be called upon to make in existing plumbing systems.

You will not find everything you need to know to become a master plumber in this training manual. However, by studying the material in this chapter and the one following, and then putting into practice what you learn, you should be well on your way toward developing the basic skills of this trade.

SEWER SYSTEMS

The main purpose of a sanitary sewage collection system is to transfer sewage from a source to a sewage treatment plant. Raw sewage that is not transferred safely to a sewage treatment plant is harmful to human beings because it contains many harmful bacteria.

The sanitary sewage collection system includes all house sewers, laterals, branches, interceptors, force mains, and so on. These and other related terms are explained in chapter 12 of this training manual. In this discussion we are primarily concerned with materials and operations required in the installation of sewer systems.

The installation of a belowground sewer system for transferring domestic sewage from the source to the sewage treatment plant includes (1) trenching and grading, (2) measuring and cutting pipe, (3) laying pipe, (4) joining pipe, (5) testing, and (6) backfilling and tamping. Let us first discuss trenching and grading; information on the other phases of sewer installation will be given in other sections of the chapter.

TRENCHING AND GRADING

A trench may be excavated either manually or with heavy equipment, depending primarily on the size of the job and the type of soil to be removed. On a large job where the soil is suitable for machine work, your project supervisor will arrange to have Equipment Operators to operate those pieces of equipment necessary to excavate or dig the trench. When it is impractical to use machines, you will have to do the job with a pick and shovel. Whichever method is used, it is important that the trench be dug wide enough (2 feet minimum) to allow ample working room to join pipe sections. It is also important that the bottom of the trench be sloped in the direction of flow so that sewage traveling through the pipeline laid in the trench will not be restricted. On most jobs, an Engineering Aid will be on hand to check elevations to ensure that the slope of the trench is close to the slope at which the pipe is to be laid. On most jobs also, Engineering Aids will establish a system of batter boards and grade bars for you to use to accurately check the slope of the pipeline as it is being laid in the trench. Check the job specifications for the proper grade of the sewerline being installed. If specifications are not available, a rule of thumb to follow is to slope the trench 1/4 inch per foot. This is the grade at which sewage will flow freely through a pipe.

When a pipeline is to be laid in a stable soil, such as hard clay or shale, the trench should be excavated below the pipe grade. If bell and spigot pipe is to be used, excavation must be made for the bells. See that a sufficient amount of undisturbed earth remains at the bottom of the trench so that the pipe—both joints and barrel—will rest on and be fully supported by undisturbed earth. In areas where the temperature drops below freezing, the trench must be excavated deep enough that the pipeline will be below the frostline. Pipes that cross under roads or areas of vehicle travel must be buried in trenches at least 4 feet deep.

The sides of excavations 4 feet or more in depth, or in which the soil is so unstable that it is not considered safe at greater depths, should be supported by substantial and adequate sheeting, sheet piling, bracing, shoring, etc., or the sides should be sloped to the angle of repose. Surface areas adjacent to the sides should be well drained. Trenches in partly saturated, filled, or unstable soils, must be suitably braced.

BELOWGROUND SEWAGE PIPING

Various types of pipe materials are used in sewage systems. However, cast-iron soil pipe, concrete, and vitrified clay are normally the materials used belowground for sewerlines installed by Utilitiesmen. These pipes have hub and spigot ends for joining them together.

Cast-Iron Soil Pipe

Cast-iron soil pipe and fittings are composed of gray cast iron of compact, close-grain, pig iron, scrap iron and steel, metallurgical coke, and limestone. Cast-iron soil pipe is normally used in and under buildings, protruding at least 5 feet from the building. Here it connects into a concrete or clay house sewerline. Cast-iron soil pipe is also used when going under roads or other places of heavy traffic.

If the soil is unstable, it will be to your advantage to use cast-iron soil pipe. However, cast-iron soil pipe should not be used in soil containing cinders or ashes, the reason being that the soil may contain sulfuric acids, which would cause the pipe to corrode and to deteriorate

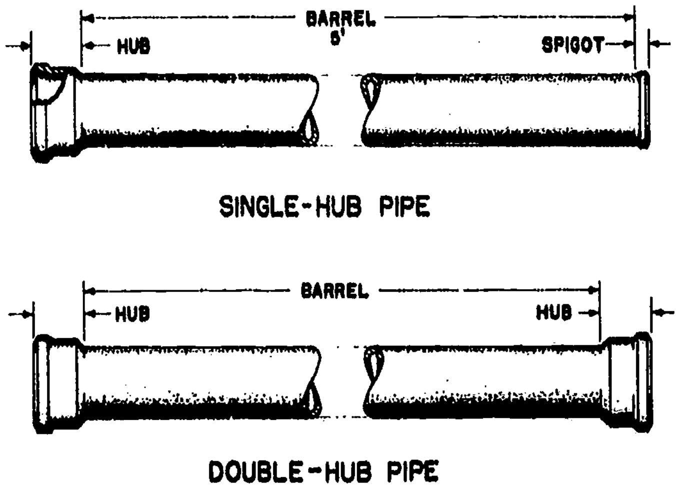

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Figure 4-1.—Single-hub and double-hub cast-iron soil pipe.

rapidly. Note: If the soil contains cinders and ashes, instead of using cast-iron soil pipe, use vitrified clay pipe.

The cast-iron soil pipe used in plumbing installations comes in 5-foot and 10-foot lengths. Sizes of cast-iron soil pipe are: 2", 3", 4", 5", 6", 8", 10", 12", and 15" nominal inside diameter. It is available as single-hub or double-hub in design, as indicated in figure 4-1. Note that single-hub pipe has a hub at one end and a spigot at the other, while a double-hub pipe has a hub at both ends. Hubs, or bells, of cast-iron soil pipe are enlarged sleeve-like fittings, which are cast as a part of the pipe and are utilized to make a water- and pressure-tight joint with oakum and lead. Cast-iron soil pipe is generally available in two weights: Standard (SV) and Extra Heavy (XH). The extra heavy pipe is used where superior strength is required, such as under roadways, where it may be subject to vibration or slight settling, and for tall stacks. Standard weight pipe is adequate for most Navy base construction.

MEASUREMENT OF CAST-IRON SOIL PIPE.—Cast-iron soil pipe sections are generally considered as being 5 feet and 10 feet in length, but strictly speaking, this is not true. The reference to a 5-foot length of pipe applies to the laying length, not the overall dimensions. For clarity, first note that cast-iron soil pipe in 2-, 3-, 4-, 5- and 6-inch (inside) diameter are sizes in common use. The length of the bell for the 3-inch diameter pipe is 2 3/4 inch; and for the 4-, 5-, and

6-inch diameter sizes, it is 3 inches. Now note that while the laying length of a 4-inch diameter cast-iron soil pipe is 5 feet, the overall dimension is 5 feet and 3 inches.

The most common measurement of cast-iron soil pipe, for a shorter length than 5 feet, is the overall measurement. When making this measurement for, say 4-inch pipe, take the desired length of pipe for the installation and add 3 inches to it for the bell.

CUTTING CAST-IRON SOIL PIPE.—Before joining cast-iron soil pipe, you will often have to cut the pipe in order to provide the length desired for the job at hand. Cast-iron soil pipe can be cut with an abrasive cutter; a band saw; a special soil pipe cutter, generally referred to as a snap-cutter; or a hammer and cold chisel. In this section we will explain how to cut cast-iron soil pipe using a hammer and cold chisel.

To cut cast-iron soil pipe, using a hammer and cold chisel, you will need the following equipment:

1. One 6-foot folding rule
2. One piece of soapstone or crayon
3. One 18'' wrap around
4. Two 2 x 4 pieces (approximately 3 feet long)
5. One hammer
6. One cold chisel
7. One pair of clear goggles

Here is the procedure for cutting cast-iron soil pipe with a hammer and cold chisel:

1. Place the cast-iron soil pipe on 2 x 4s, one on each end of the pipe on the floor or ground, so it can be steadied with your knee.

2. Measure the length of the piece to be cut and mark this length on the pipe with an arrowhead (see view A, fig. 4-2).

3. Establish a line around the pipe using a wrap-around and a piece of soapstone or crayon. This will aid you in cutting the pipe squarely.

4. Place one 2 x 4 under the pipe where the cut is to be made.

5. Hold the cutting edge of the chisel firmly and squarely against the pipe at the mark and strike with the hammer, scoring the cast-iron soil pipe lightly (see view B, fig. 4-2).

6. Rotate the pipe slightly and place the cold chisel against the mark and strike it again with the hammer.

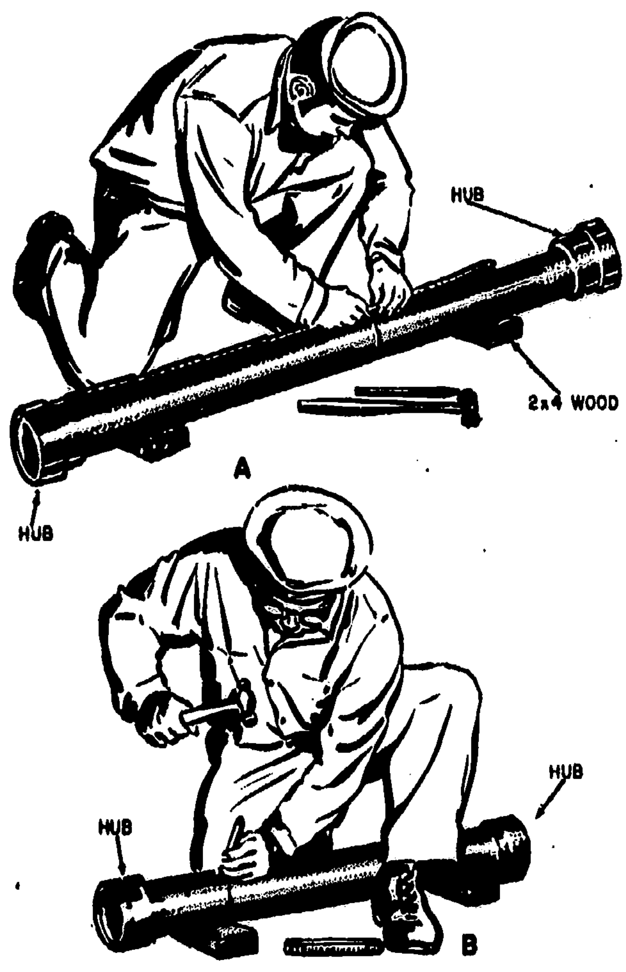

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Figure 4-2.—Measuring and cutting cast-iron soil pipe.

7. Repeat steps 5 and 6 until the pipe has been evenly scored on its whole circumference.

8. Gradually increase the force of the blows with the hammer, while rotating the pipe, deepening the score, until the pipe breaks evenly around the scored mark.

CAUTION: Use very light blows of the hammer until the cast iron has been scored all the way around, to prevent the pipe from breaking jaggedly and rendering it valueless.

A point to remember is that, if you have to cut a short piece of cast-iron soil pipe, cut it from a double-hub pipe, because the remaining pipe still has a hub and it is still good for future use. However, when you cut off the hub from the single hub, the remaining portion of the pipe is usually wasted.

CAST-IRON SOIL PIPE FITTINGS. — Cast-iron soil pipe fittings are used for making branch connections, or changes in the direction of a line. Both cast-iron soil pipe and fittings are brittle, so exercise care to avoid dropping them on a hard surface. Some of the cast-iron soil pipe fittings which you may use in your work are described below.

Bends. — A number of different types of bends are generally used on jobs involving cast-iron soil pipe. Among common types are the 1/16th, 1/8th, short sweep 1/4, long sweep 1/4, and reducing 1/4 bend. By observing figure 4-3, you will get an idea of the shape and appearance of each of these types of bends.

The 1/16th bend is used to change the direction of a cast-iron soil pipeline 22 1/2 degrees. A 1/8th bend is used to change the direction of a cast-iron soil pipeline 45 degrees. The SHORT SWEEP 1/4 bend is a fitting used to change the direction of a cast-iron soil pipeline 90° in a close space. The LONG SWEEP 1/4 bend is used to change the direction of a

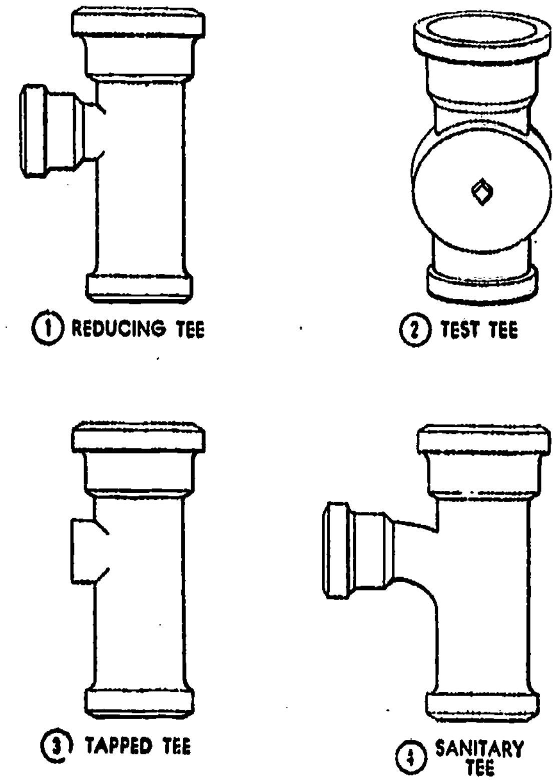

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Figure 4-4. — Cast-iron soil pipe tees.

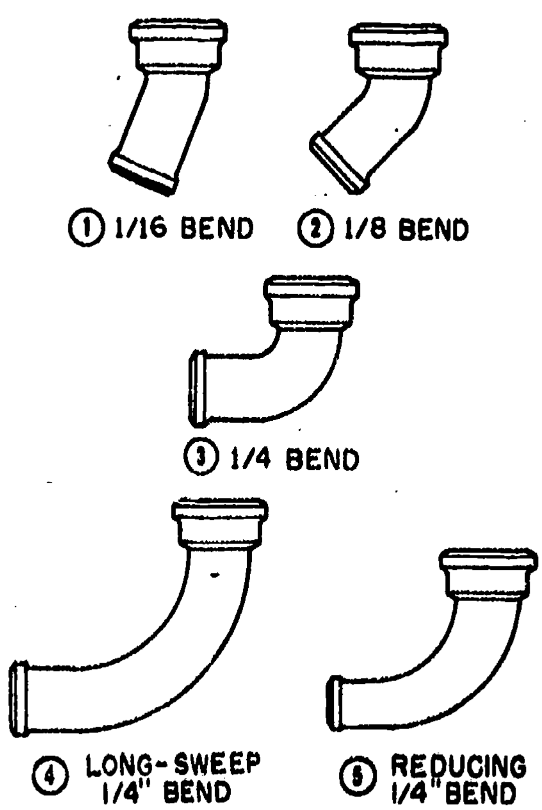

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Figure 4-3. — Types of cast-iron soil pipe bends.

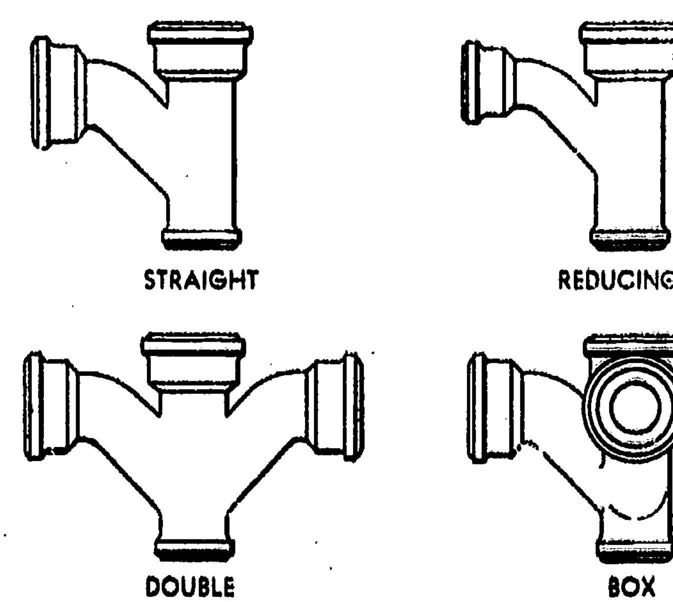

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Figure 4-5. — Types of cast-iron soil pipe 90° Y-branches.

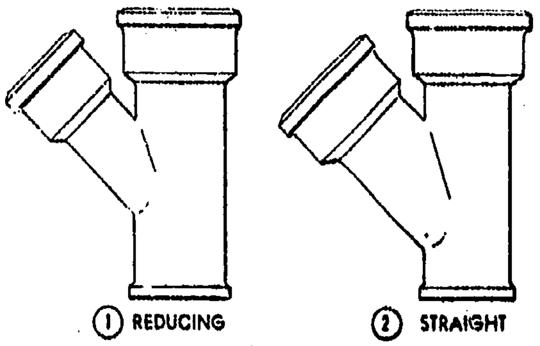

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Figure 4-6.—Types of cast-iron soil pipe 45° Y-branches.

cast-iron soil pipeline 90° more gradually than a quarter bend.

The REDUCING 1/4 bend changes the direction of the pipe gradually 90° and in the sweep portion it reduces nearly one size. A 4 by 3 reducing long-sweep 1/4 bend, for instance, has a 4-inch SPIGOT on one end, reducing in 90° to a 3 1/4-inch HUB on the other end. Note that for all CISP (cast-iron soil pipe) fittings the spigot end always is listed first.

Tees.—Tees are used to connect branches to continuous lines. Learn to recognize the four designs of tees shown in figure 4-4.

For connecting lines of different sizes, REDUCING tees often are suitable.

The TEST tee is used in stack and waste installations where the vertical stack joins the horizontal sanitary sewer. It is installed at this point to allow the plumber to insert a test plug and fill the system with water while testing for leakage. (The test tee also is used in multi-story construction.)

The TAPPED tee is frequently used in the venting system, where it is called the main vent tee. The SANITARY tee is commonly used in a main stack to allow the takeoff of a cast-iron soil pipe branch.

Ninety Degree Y-Branches.—Four types of cast-iron soil pipe 90° Y-branches generally used are illustrated in figure 4-5. These are normally referred to as combination Y and 1/8th bends.

The STRAIGHT type of 90° Y-branch has one straight-through section and a takeoff on one side. The side takeoff starts out as a 45° takeoff and bends into a 90° takeoff. This type

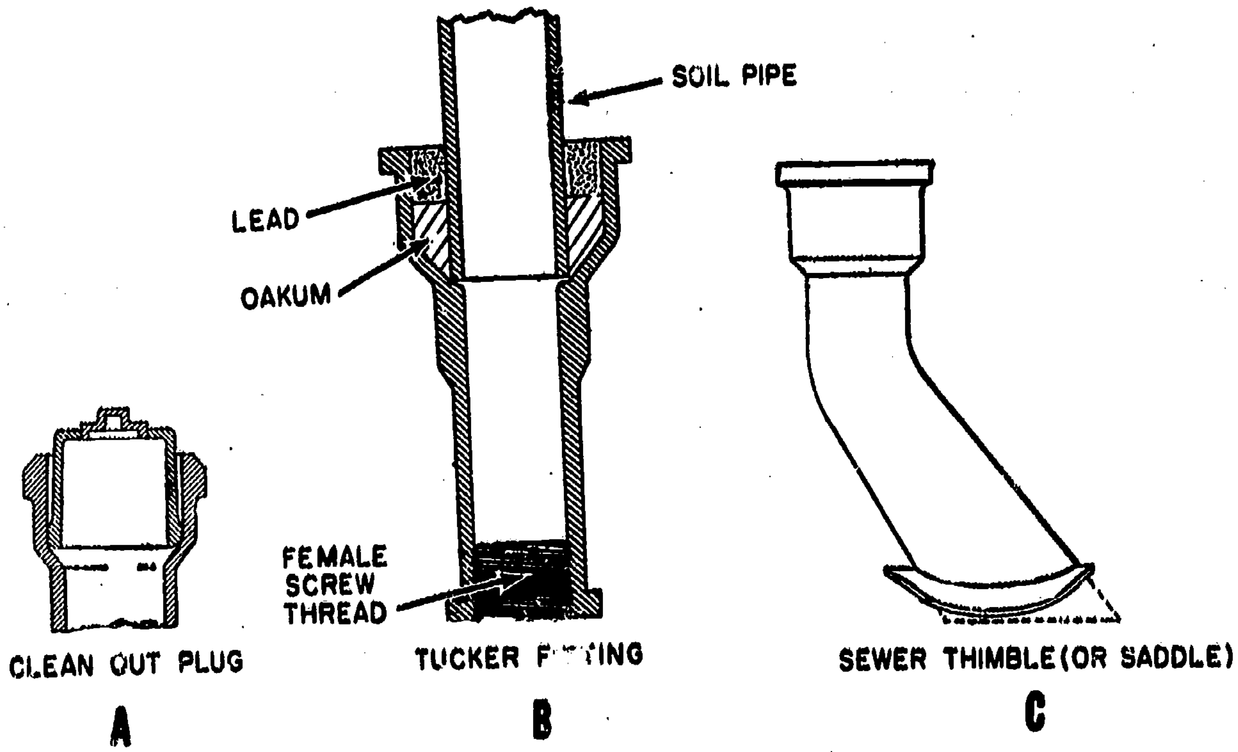

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Figure 4-7.—Adapter type cast-iron soil pipe fittings.

is used in sanitary sewer systems where a branch feeds into a main, and it is desirable to have the incoming branch feeding into the main as nearly as possible in a line parallel to the main flow.

The REDUCING 90° Y-branch is similar to the straight type. But as indicated in figure 4-5, the branch takeoff of the 90° Y-branch is of a smaller size than the main straight-through portion. Its general use is the same as the straight type except that the branch coming into the main is a smaller sized pipe than the main.

The DOUBLE 90° Y-branch (or DOUBLE COMBINATION Y and 1/8th BEND) is easy to recognize since there is a 45° takeoff bending into a 90° takeoff on both sides of the fitting (see fig. 4-5). It is especially useful as an individual vent.

The BOX type of 90° Y-branch has two takeoffs. It is designed so that each takeoff forms a 90° angle with the main pipe. The two takeoffs are spaced 90° from each other.

Forty-Five Degree Y-Branches.—Two types of cast-iron soil pipe 45° Y-branches are the reducing and the straight types, both shown in figure 4-6.

The REDUCING type is a straight section of pipe with a 45° takeoff of smaller size branching off one side. You will use different sizes of this fitting. As an example, a 4 by 4 by 3 reducing 45° Y-branch would have a 4-inch straight portion with a 3-inch 45° takeoff on one side.

The STRAIGHT type of 45° Y-branch, or true Y, is the same as the reducing type except that both bells are the same size. It is used to join two sanitary sewer branches at a 45° angle.

Cleanouts.—Cleanout plugs are installed to allow the removal of stoppages from waste lines. Figure 5-7A shows one type of cleanout plug. It consists of an iron ferrule which is calked with the hub of a pipe or fitting. Its top opening is taped and threaded to allow for a pipe plug to be screwed into it.

Cleanouts should not be more than 50 feet apart in horizontal 4-inch building drain lines in a straight run. When the change of direction is greater than 45° (or a 1/8th bend), a cleanout must be installed.

Adapters.—A Tucker type cast-iron soil pipe drainage adapter is a specialized fitting used to connect a bell and spigot pipe section to a threaded pipe section. (See fig. 4-7B.) It is recommended especially for pipe joints where unions are not desirable. The adapter has a bell at the top and a female screw thread on the bottom. To insert the adapter in a line, slide the bell up on the spigot of the bell and spigot pipe until it clears the male thread on the threaded pipe. The adapter should be screwed onto the threaded pipe with a wrench; the bell is then calked with oakum and lead.

Another type of adapter is a sewer thimble (or saddle). This is a specialized fitting, which is used to tie into an existing sewerline. (See fig. 4-7C.) It has a hub on one end, bending around to almost 45°, with a flange near the opposite end. You may also cut one hub off of a double hub pipe and use that when no sewer thimble is available.

To install, cut a hole halfway between the top and centerline in the sewerline about the same size as the outlet portion of the thimble beyond the flange. Slip the thimble into the opening until the flange seats on the sewer pipe. Using oakum and concerte, grout around the thimble to make a watertight joint.

JOINING CAST-IRON SOIL PIPE.—Various methods are used in joining pipe. This means that you must know the procedure to follow in making various types of joints required for the kind of pipe to be joined. Joints in cast-iron hub-and-spigot soil pipe are made by calking with oakum and lead. However, if oakum is not available, cotton braid or jute may be used as a substitute. Oakum is made of hemp or jute fibers, impregnated with a bituminous compound and loosely twisted or spun into a rope or yarn.

In making calked joints you will use various types of equipment. In view of the importance of this equipment, we will briefly discuss some of the common types of calking equipment before describing specific procedures to follow in making calked joints.

Calking Equipment.—Equipment frequently used in making calked joints in cast-iron soil pipe includes the melting furnace, melting pot, and plumber's ladle, illustrated in figure 4-8A. The metaling furnace is a portable, fuel-burning furnace, used to melt lead. The melting pot is made of cast iron and is used to contain the lead while it is being melted on the furnace. The ladle, also made of cast iron, is used to spoon up the molten lead and carry it to the joint to be poured.

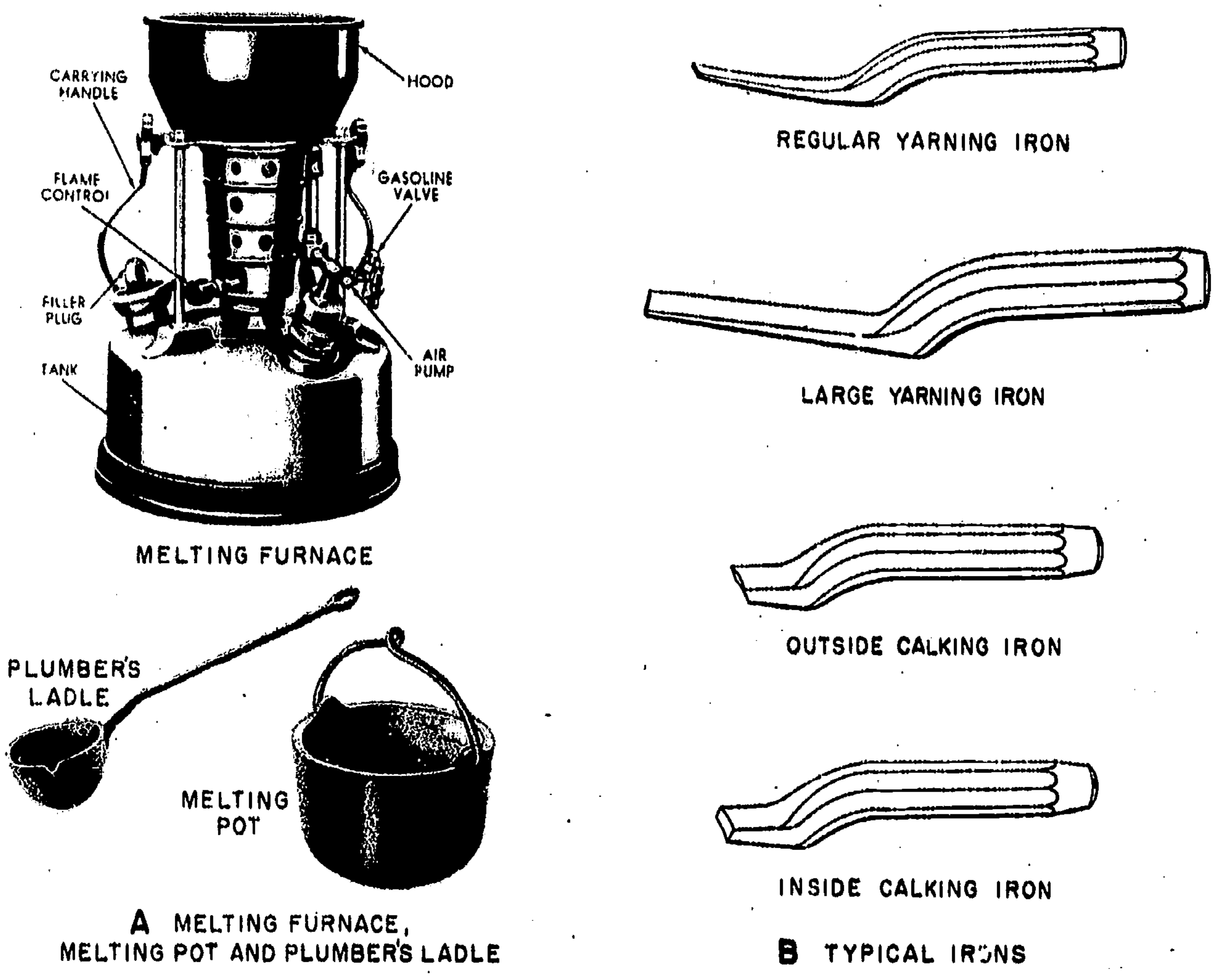

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Figure 4-8. — Equipment used in making lead joints.

Several types of melting furnaces are available, and the manufacturer's instructions should be followed in operating any particular type. The general procedure below is for operating a gasoline-burning melting furnace.

1. Inspect the melting furnace and see that the tank, located in its base, is filled 3/4 full with gasoline; use unleaded (white) gasoline. Be sure that all joints on the melting furnace are tight and that the filler plug is screwed firmly into place.

2. Using the small airpump built into the melting furnace, charge the melting furnace with air. Pump up and down vigorously on the handle 25 to 50 times to create air pressure inside of the gasoline tank. This forces gasoline under pressure through the orifice to the burner under the melting pot.

3. Open the gasoline valve a half turn and allow liquid gasoline to accumulate in the small trough below the coil. When the trough is full, shut off the gasoline valve.

4. Light the gasoline in the trough with a match or a rolled up piece of paper. Stand back as far as possible while lighting the melting furnace since there may be a small puff of flame when the gasoline ignites.

5. Allow almost all of the gasoline in the trough to burn, heating the coil through which the fuel is sprayed sufficiently to cause the liquid gasoline to vaporize before it hits the bottom of the melting pot.

6. Carefully open the main gasoline valve to allow a small flow of gasoline from the tank up to and out of the orifice. Do not open the valve any more than necessary to produce a hot blue or almost colorless flame around the bottom of the melting pot.

7. Place one or two ingots or cakes of lead in the melting pot and allow them to melt.

Instead of the gasoline furnace discussed above, other types of melting furnace also are available. One type that you would find very satisfactory is the butane furnace. Whatever the type available, remember to follow the manufacturer's recommendations for using and maintaining the furnace.

While molten lead is an inherently dangerous substance to use, most accidents on the job may be attributed directly to the failure of the mechanic to observe proper safety precautions. When handling molten lead, be SAFETY MINDED.

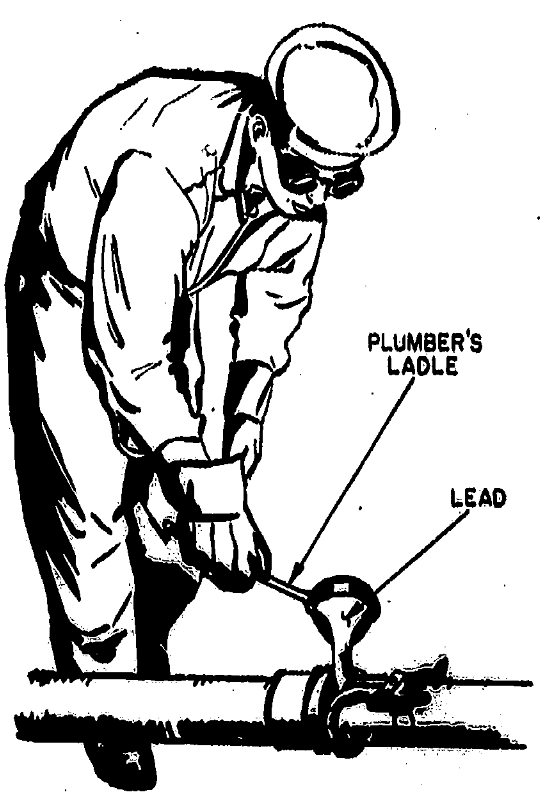
Most accidents are caused by splashing of lead from the melting pot because of the introduction of water in some form into the molten metal. If there is reason to suspect the presence of moisture in lead for melting, the lead should be heated with a gasoline blow torch until all of the moisture is driven off before adding the lead to the melting pot. Failure to completely dry any lead will mean that the moisture will be converted rapidly into steam when it strikes the molten lead. The resulting rapid expansion of this steam will splash lead out of the melting pot. This can have serious consequences. The lead sometimes spatters to a height which might reach the face or eyes. The plumber's ladle used for handling the lead must also be free of moisture.

When lead is melted, certain products of oxidation known as slag form on top of the molten metal. The slag must be removed from the lead before it can be used for pouring a joint. This is done by scooping it up in the plumber's ladle. Use care in the disposal of the slag.

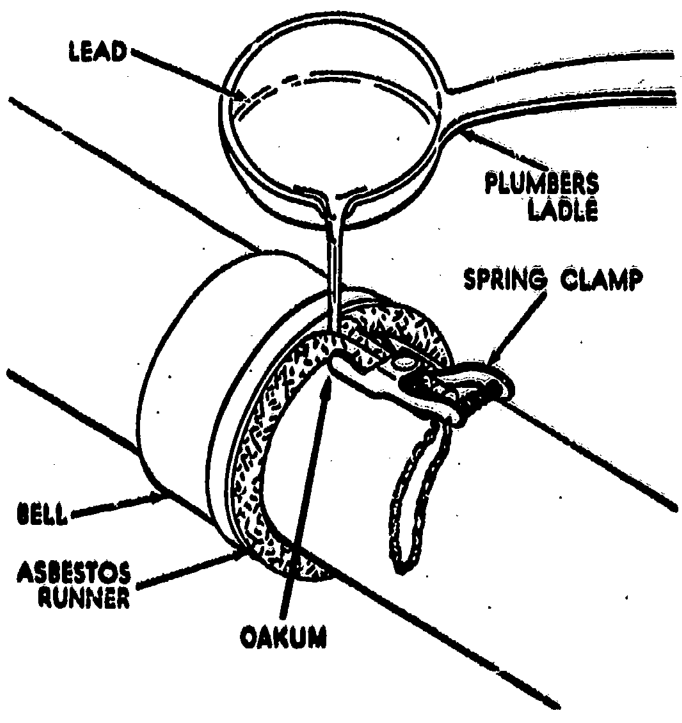
Always preheat the ladle before you dip it into the lead. The reason for this is that a cold ladle chills and solidifies some metals. When the ladle is in steady use, keep it hot by hanging it over the edge of the pot. In loading the ladle, use the bottom of it to push back the dross (or scum) on top of the lead, exposing enough clean lead so that the ladle can be filled and withdrawn without dross. Do not disturb the molten lead more than is necessary.

Wear goggles, gloves, and protective clothing when melting and pouring the lead. Keep out of range of flying lead even though the joint appears dry. Also, see that drops of perspiration do not drop into the pot of hot lead.

Keep the melting pot clean. Dross and lead oxide can be removed with a sharp chisel, after



29.208(54)
Figure 4-9. — Pouring lead into joint.



29.208
Figure 4-10. — Joint runner in place.

which the pot can be further cleaned with a wire brush.

In joining cast-iron soil pipe by calking, you will also use various types of irons to help ensure that the joints are made watertight. Yarning irons are used to tamp oakum into the hub of hub-and-spigot pipe when making up a joint. They are available in a variety of sizes and patterns, two of which are the regular and the large pattern illustrated in figure 4-8B.

Calking irons are used to drive poured lead or lead wool against the oakum and the hub and spigot of a calked joint. They are available in a large number of styles and patterns and are either inside or outside irons; both these types are also illustrated in figure 4-8B. The outside calking iron is used on the lead close to the hub, and the inside iron is used on the lead close to the spigot.

Poured-Lead Joint.—In making a poured-lead joint in cast-iron soil pipe, follow the general procedure outlined below.

Wipe the hub and spigot ends of the pipe dry and free from foreign material before assembling and pouring the lead. Moisture causes molten lead to fly out of the joint and serious injury may result. In case lead MUST be poured into a wet hub, sprinkle powdered rosin or oil in the joint to reduce the tendency of the molten lead to fly out.

See that the pipe to be installed is placed in the hub of the soil pipe and is centered to provide a uniform thickness of the joint.

Yarn in oakum, using a yarning iron, to within about 1 inch of the top of the hub. Note that you will need 1 pound of lead for each inch of pipe diameter. Hence, a 4-inch joint will require 4 pounds of lead; and sixteen 4-inch joints would require 64 pounds of lead. Note, also, that oakum is figured at 10% of the amount of lead required. So, a job that requires 1,000 pounds of lead will need 100 pounds of oakum.

Using the ladle, dip out lead from the melting pot and fill the joint even with the hub. (See fig. 4-9.) As a pointer on technique, fill the joint completely with one pour of lead.

After the lead has hardened, move the calking iron all the way around the joint and tamp it firmly but gently using a light ballpeen hammer to make the joint watertight. Be sure and exercise care in tamping. If the calking iron is struck too hard, the cast-iron hub may crack, in which case replacement of the hub, as well as the pipe, would be necessary.

Horizontal Lead Joint.—If the joint to be poured is HORIZONTAL (as well as inverted or upside down) you will need to use a joint runner, also known as a pouring rope. The joint runner serves to keep the lead inside the hub. One type of joint runner is made of asbestos and is fastened in place by means of a spring clamp, as illustrated in figure 4-10. A joint runner made of fiber and hard rubber (not shown) also is available. This type fits snugly around the pipe and against the hub. It is provided with a pouring groove on the upper side to facilitate pouring the molten lead.

When a joint runner is used, the procedure is practically the same as described above for the poured-lead joint. Pack the joint with oakum. Then place the joint runner around the spigot end of the pipe and push it flush against the bell end of the other pipe, sealing the joint except for a small hole at the top. The joint runner should be tapped lightly against the hub of the joining bell to prevent leakage of molten lead. Next place a small piece of oakum between the clamp and pipe to seal the gap and prevent hot lead from running out of the joint. Then proceed as previously described.

Lead-Wool Joint.—In making a LEAD-WOOL JOINT in cast-iron soil pipe, you will need a yarning iron and calking irons. This is a cold-calked joint and should be used where a line is under water or in a wet place where molten lead cannot be used.

Before actually starting the joint, place the spigot end of the pipe to be installed in the hub of the soil pipe. Make sure the pipe is securely blocked with braces to prevent shifting. It is also important that the pipe be centered in the hub so the thickness of the joint will be uniform.

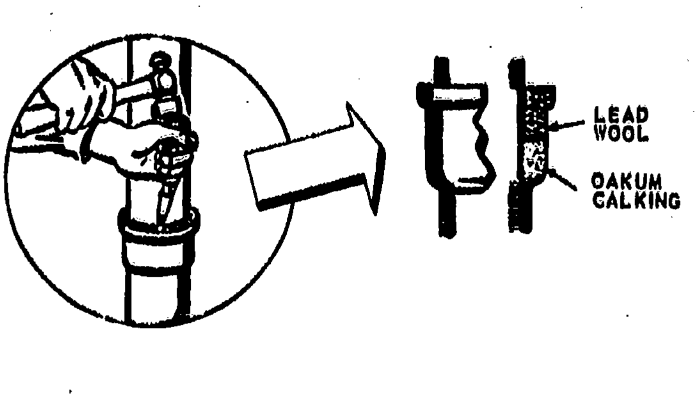


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Figure 4-11.—Tamping lead wool.

With the pipe braced firmly and in proper position for joining, now make the joint, following the procedure given below:

Pack oakum in the joint to within 1 inch of the top of the hub. Use a ballpeen hammer and packing iron to tamp the oakum tightly in the joint.

Pack two 1/2-inch layers of lead wool over the oakum.

Tamp the lead wool tightly into the joint, using calking irons and ballpeen hammer (see fig. 4-11).

Vitrified Clay and Concrete Pipe. — Vitrified clay pipe is made of moistened powdered clay. It is available in laying lengths of 2, 2 1/2, and 3 feet and in diameters ranging from 4 to 42 inches. Like cast-iron soil pipe, it has a bell end and a spigot end to facilitate joining. After the pipe is taken from the casting, it is glazed and fired in large kilns to create a moisture-proof baked finish. It is used for house sewerlines, sanitary sewer mains, and storm drains. The types of fittings for clay pipe are few: bends, T's and Y-branches primarily.

You may have occasion to use plain precast concrete pipe for sewers in the smaller sizes — less than 24 inches. This pipe is not reinforced with steel. This concrete pipe is similar to vitrified clay pipe in measuring, cutting, and handling.

CUTTING. — Vitrified clay and concrete pipe, since both are available in such short lengths, seldom need cutting except at manholes and inlets. If, after measurement, it is necessary to cut vitrified clay or concrete pipe, score it with a chisel, deepening the cut gradually until the pipe breaks cleanly at the desired point. Vitrified clay and concrete pipes may be cut with CISP "snap-off" or "chain" cutters.

FITTINGS. — Figure 4-12 shows some common fittings used with vitrified clay and concrete pipes. It should be noted that these types of pipes are used outside the building, which greatly reduced the number of different types of fittings necessary.

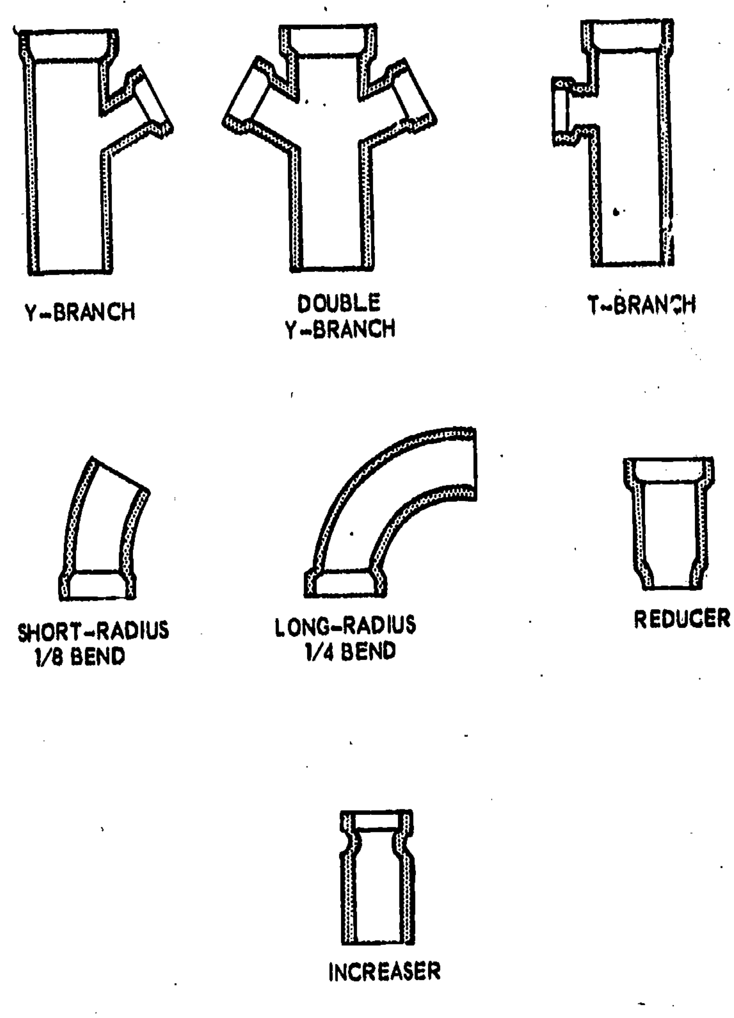

Figure 4-12. — Cross section of clay or concrete fittings.

JOINING. — Joints on vitrified clay and concrete pipe may be made of cement or bituminous compounds. Cement joints may be made of grout: i.e., a mixture of cement, sand, and water. The following procedure may be used as a guide in joining with grout; the procedure is similar when joining with bituminous compounds.

INSERT the spigot of one length of pipe into the bell of another and align the two pieces to the desired position.

CALK a gasket of oakum about 3/4" thick into the bell to prevent the grout from running into the pipe.

MIX GROUT, using one part Portland cement, two parts clean sharp washed sand, and sufficient water to thoroughly dampen.

FILL THE JOINT with grout using a packing tool.

RECALK THE JOINT after 30 minutes using a packing tool. This is necessary to close shrinkage cracks which occur after the initial set of the grout.

SMOOTH AND BEVEL the grout off with a trowel. In hot weather, cover the joint with wet burlap sack.

REMOVE excess mortar with either a swab or a scraper.

Note that a regular swab, with some additional rags tied to the end to compensate for larger size pipe, is ideal to drag through each length to remove excess mortar.

The use of "speed seal joints" (rubber rings) in joining vitrified clay pipe has become widespread. Speed seal joints eliminates the use of oakum and mort joints for sewer mains. This speed seal is m part of the vitrified pipe joint at the time of manufacture. It is made of permanent polyvinyl chloride and called a plastisol joint connection. This type of joint helps to ensure tight joints that are root proof, flexible, etc.

The speed seal, or mechanical seal, joint can be installed quickly and easily by one man. To make the joint, first insert the spigot end into the bell or hub. Then give the pipe a strong push so that the spigot locks into the hub seal. A solution of liquid soap may be spread on the joint to help it slip into place easily. You will find that other types of mechanical seal joints also are available, all using about the same method of installation.

Incidentally, special mechanical seal adapters are available for joining vitrified cla pipe to cast-iron soil pipe or soil pipe to vitrified pipe.

Laying Sewer Pipes

Small pipes can be assembled and joined in sections on top of the ground and laid in the trench by hand. Large, heavy pipes are usually laid in the trench and then joined. These pipes may be lowered into the trench by rope, cable, or chain, while still others may require the use of machinery operated by an Equipment Operator.

When assembling and joining pipes outside the trench, make sure you are a safe distance from the edge of the trench to prevent cave-ins. Also, do not leave tools or materials near the edge of a trench where they may be knocked off and possibly injure someone working in the trench, or cause a worker to lose his footing and fall into the trench.

Sewer pipes should be laid on a compacted bed of sand, gravel, or material taken from the trench excavation, if suitable, in order to provide a slightly yielding and uniform bearing. This will assure safe support for the pipe, fill, and surface loads. When pipes are laid on sand, gravel, or similar material, the weight of the pipe will usually provide a suitable equalizing bed.

Pipelines should be embedded carefully so that they do not settle at any point. Settling causes suspended matter to collect in the lower portion of the pipe, restricting the flow and reducing the capacity of the line.

Checking Grade of Sewerline

After you have laid the pipes, your next step is to check the grade and align the pipeline. This is very important in installing a below-ground sewer system. Remember that sewage will not flow uphill. The pipe is laid with the hub end upstream, and the laying proceeds upgrade. The spigot is inserted into the hub of the previously laid length. Each length is checked as to its grade and alignment before the next length is placed.

When grading for the proper pitch per foot the method illustrated in figure 4-13 may be used as a guide. This illustration shows a ditch with batter boards used in transferring line and grade to trench; a stick for checking grade is shown in position.

The Engineering Aid will be responsible for setting the batter boards at the proper level for the job at hand. Batter boards are placed across the trench at about 25- to 50-foot intervals. Elevations are run by the EAs and a mark is placed on the stakes at some even foot distance above the invert (which is the lowest point on the inside of the pipe) of the sewer. A nail is then driven in the top of the batter boards and a cord is stretched from board to board.

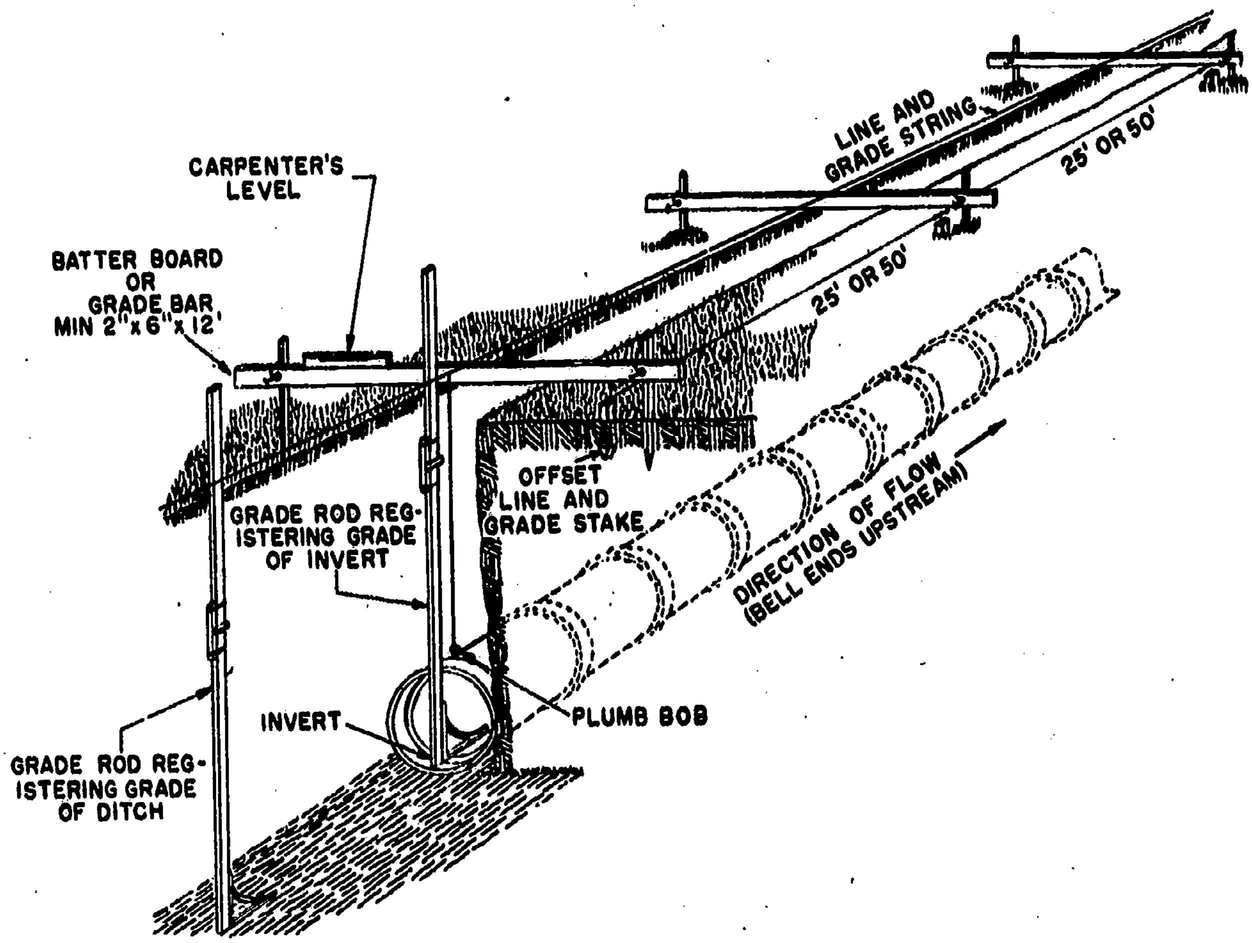

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Figure 4-13. — Laying sewer pipe to line and grade.

The centerline for the pipe is then transferred from the cord to the bottom of the trench by means of a plumb bob. Grade is transferred by means of a stick, marked in even foot marks having a short piece fastened at a right angle to its lower end. Grade is checked by placing the short piece on the invert of each length of sewer pipe and aligning the proper mark on the grade rod to the cord.

Testing

The purpose of testing any pipeline is to make sure the joints are tight enough to withstand working pressure. Since sewerline of this type will be of gravity drainage, the test procedures will be different than those described later under water service.

Before pipe is covered with dirt it must be tested for leakage. There are several methods of effecting this test. The most widely used test is the water test, although an air test or odor test may be used.

WATER TEST.—Here are the main steps to follow in making a water test. At the lowest point of the section to be tested, insert a test plug in the open end of the pipe or at a test tee and plug other openings. Fill the pipe to its highest level with water; about a 10 foot head is all that is necessary. Leave the water in the pipe for at least 15 minutes prior to starting any test. This will allow the oakum to soak up some water before looking for leaks. Refill the pipe, if necessary to overflow and check each joint for leaks.

AIR TEST.—Before making an air test, fill the system with water and allow it to stand until the oakum expands at the joints. Drain the water from the lines and reinsert the test plug. Close all openings and apply an air pressure of at least 5 pounds per square inch (psi).

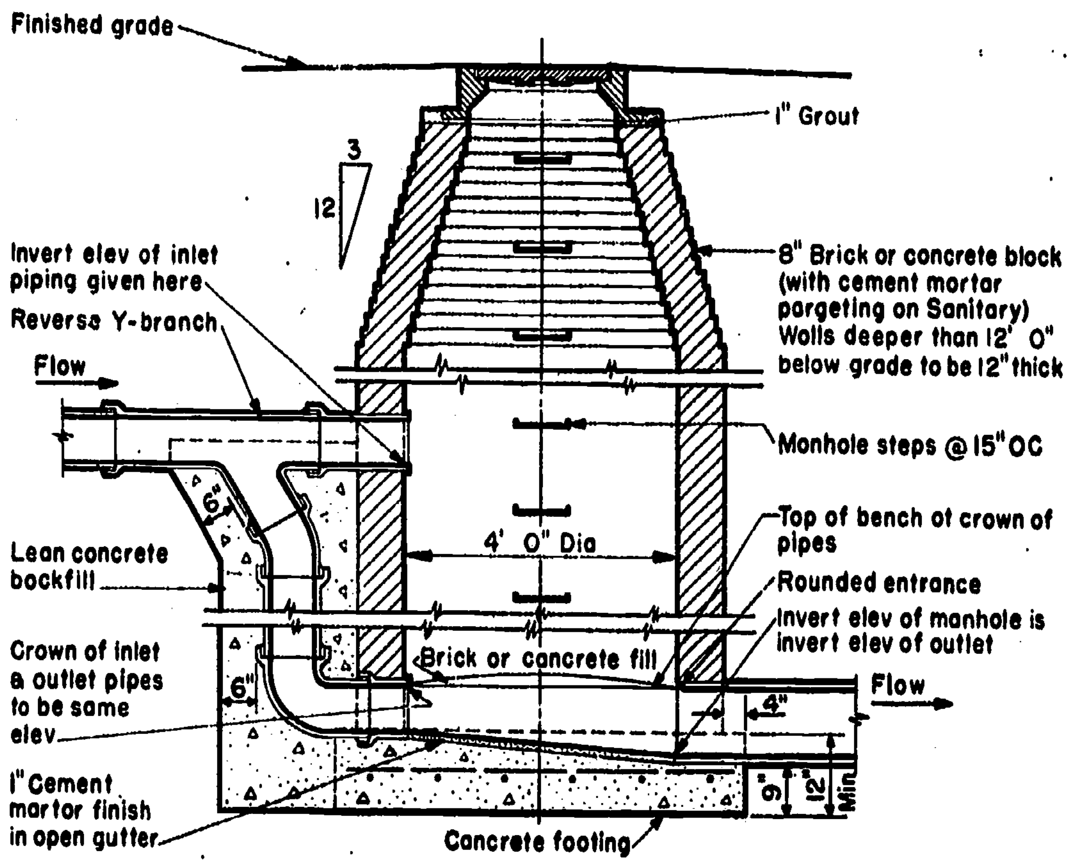

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Figure 4-14.—Standard drop manhole for sanitary and drainage systems.

In a satisfactory test the line should hold 5 psi for 15 minutes. If it does not, cover the joints with a soapy water solution and check for bubbles at the leak.

ODOR TEST.—Prior to making an odor test, all openings in the sewer and branches must be plugged. After sealing the openings, pour 2 ounces of oil of peppermint in each line or stack. Then pour approximately 5 gallons of boiling water in the stack and seal it. The odor of peppermint at any point in the installation will indicate a leak. The inspector checking the installation for leaks should not be near the oil of peppermint at any time prior to the inspection, since such exposure would rapidly dull his sensitivity to the odor of peppermint. The peppermint test is not as conclusive in its results as the water and air tests described above, since no pressure is on the pipe.

NOTE: Repeat all tests as necessary until all leaks are found and repaired.

Manholes

Under normal conditions it will not be your responsibility as a Utilitiesman to construct manholes as they are mostly made out of concrete or brick. However, you will be working with the Builders in spotting the location for the manholes. Figure 4-14 shows a typical drop manhole. Below is a description of a typical manhole.

Watertight manholes of brick or concrete, 4 ft in diameter at sewer level, should be placed at junctions and bends in the line. They are spaced preferably 300 ft apart for 8-in. pipe, 400 ft for 10- to 15-in. pipe, 500 ft for 18- to 48-in. pipe, and 600 ft for larger sizes. Sewers should be laid straight to line and grade between manholes, and any change in the size of sewerlines must take place only at the manholes. The crown of the outlet pipe from a manhole should be on a line with or below the crown of the inlet pipe. When the invert of the inlet pipe is more than 2 ft above that of the outlet pipe, a drop manhole must be provided to conduct the sewage to a lower level with minimum turbulence.

Backfilling and Tamping

After all pipelines have been laid and tested they are ready to be covered up; this process is known as backfilling and tamping. The method described below should give satisfactory results where sewerlines are concerned.

Fine material, free from stones and other debris, is tamped in uniform layers with a small hand- or air-operated tamper under, around, and over the pipe. Use a hand shovel to backfill the ditch until the pipe has a 2-foot covering. This fill should be placed in the ditch and tamped in 4-inch layers or less. It should proceed evenly on each side of the pipe so that injurious side pressure cannot occur. Make sure you do not walk on the pipe until you have at least 1 foot of soil tamped over the pipe. Until 2 feet of fill has been placed over the pipe, the filling should be done carefully with hand shovels; after that, machinery may be used for faster backfilling. However, do not let the machinery run over the line.

Puddling or flooding with water to consolidate the backfill should not be done for a sewerline. The sections of pipe used are in short lengths and will tend to settle very rapidly to form pockets or low spots in the line.

ABOVEGROUND SEWAGE PIPING

After installing the belowground piping, the next phase in the installation of a sewer system involves installation of the aboveground piping. Information on materials used and procedures applicable to installing aboveground sewage piping is given in the following sections.

Types of Pipes

A number of different types of pipes are used in the aboveground and interior parts of a plumbing system. Some of the common types of pipes with which you should be familiar are discussed briefly below.

While GALVANIZED WROUGHT-IRON PIPE is an excellent material for aboveground plumbing, a big drawback to its use lies in its cost. It is available in lengths from 18 to 22 feet. Galvanized wrought-iron pipe is constructed of wrought iron dipped in molten zinc. This protects it from corrosion and provides high resistance to acid waste.

Acid-resistant CAST-IRON pipe is composed of an alloy of cast iron and silicon. It is used to serve chemical laboratories and other installations through which waste of an acid nature flows. In handling acid-resistant pipe such as Durion, you will need to exercise care because it is very brittle and cracks easily. It is cast in 5-foot lengths, and comes in single and double hubs.

BRASS PIPE, another aboveground plumbing material, consists of an alloy of zinc and copper. Brass pipe has a smooth interior and can resist most acids; however, it is expensive to use. It is available in 20-foot lengths, and because of its tendency to bend it must be supported at intervals of 8 to 10 feet.

Lead or lead-lined STEEL PIPE is sometimes used to carry distilled water for batteries. However, tin-lined, block tin, glass, or some types of plastic pipe must be used where no impurities are acceptable. Because it bends easily, lead pipe must be well supported. It is available in three weights: (1) standard, (2) common, and (3) extra heavy. The standard weight is commonly used.

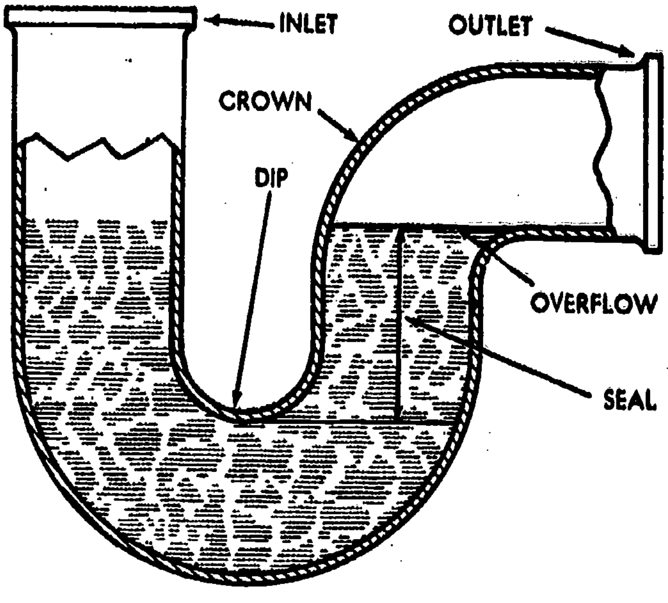

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Figure 4-15.—P-traps.

COPPER PIPE is suitable for use in waste, vent, and water installations. One point to remember is that ammonia affects copper lines. Also, when copper is used for waste pipe installations, always make sure it is rigid. This is necessary to overcome sagging. You can obtain the pipe in convenient lengths, then cut it to the size needed for the job at hand.

ROUGHING-IN

The term ROUGHING-IN refers to the water supply and waste pipes which make up that part of the plumbing system usually concealed in the walls and floors, and usually installed while the building is being framed. Since fixtures are not installed in roughing-in, see that all openings are capped or plugged. This prevents dirt and refuse from entering the system and causing stoppages later.

Roughing-in plans for a building are usually drawn up by an architect. It is important that you follow specifications on roughing-in plans which concern the location of pipes, types and sizes of materials, and outlets for fixtures.

In performing roughing-in duties you may often find symbols used to designate pipes, fittings, or fixtures, so familiarize yourself with the symbols shown in chapter 3 of this training manual.

TRAPS

A number of different types of traps are available. At present, however, the trap generally used in connection with plumbing fixtures is the P-trap (see fig. 4-15). Thus, it is with the P-trap that we are primarily concerned in this discussion.

Traps are a necessary part of the plumbing installation because they provide a means of preventing sewer gases from entering the building. Protecting occupants in a building against exposure to sewer gases is vitally important since many of these gases can cause serious illness and even death.

The term TRAP SEAL refers to the water which is held in the bent portion of a fixture trap (see fig. 4-15). True to its name, the trap seal forms a "seal" against the passage of sewer gases through the trap and into the building. The most frequently used common seal trap has a depth of 2 inches between the overflow and the dip. The deep seal trap has a depth of 4 inches.

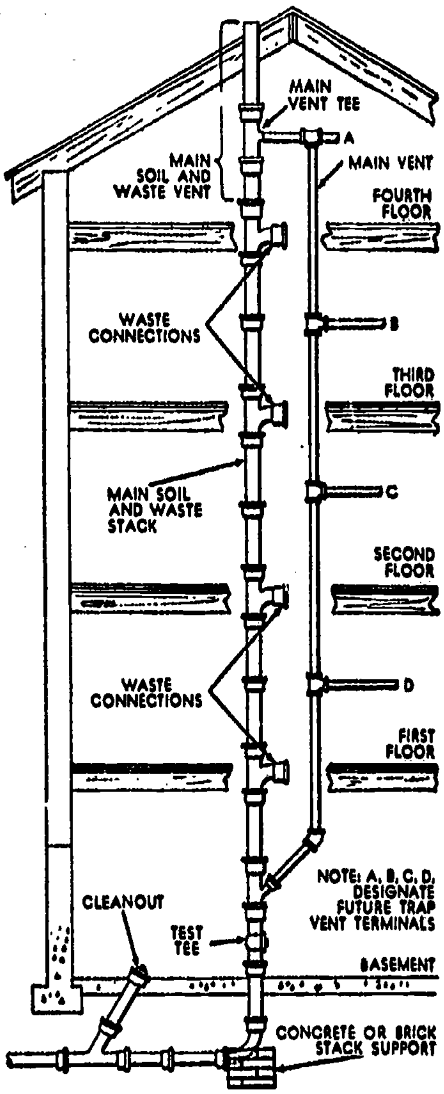

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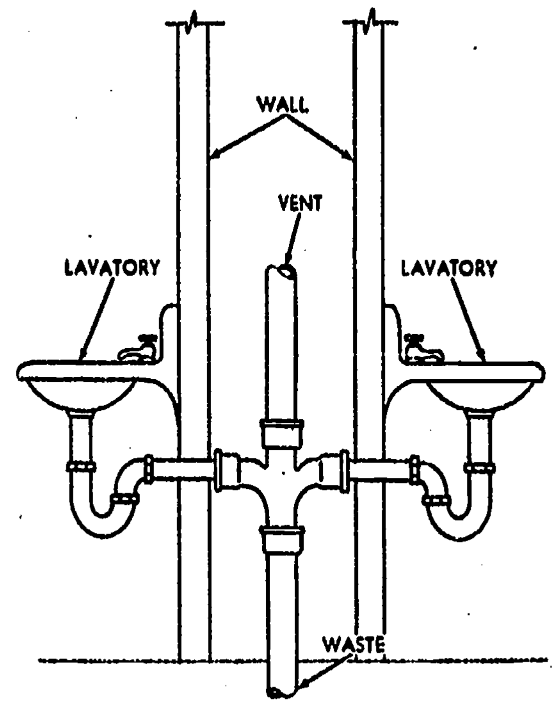
Figure 4-16. — Typical stack and vent installation.

The P-trap is so-named because its general shape is that of the letter P. It comes in sizes from 1 1/4 to 6 inches in diameter. Various types of P-trap are available, so designs may differ from one manufacturer to another. The P-trap is usually made of nickel or chrome-plated brass, galvanized malleable and cast iron, and other metal alloys.

The P-trap is used for fixtures suspended from the walls or supported on pedestals; for instance, lavatories, sinks, and urinals. At times, the P-trap may also be suitable for use in connection with shower baths and installations that do not require wasting of large amounts of water.

When using a P-trap for fixtures suspended from the wall, see that it is installed as close to the fixture as possible. You must also exercise care NOT to require too long a vertical leg between the trap and the fixture proper. See that the dip portion of the trap is at least 2". It is also important that the horizontal leg connection to the waste system be short for ventilation purposes.



54.40
Figure 4-18. — Two fixtures unit vented.

VENTS

To prevent the siphonage of the trap seal in fixture traps, air from outside the building is introduced to the outlet (or discharge) end of the trap. The air is supplied through pipes or VENTS. This air provides a pressure on the outlet end of the seal which is equal to pressure on the inlet end.

To avoid confusion, let us explain that atmospheric pressure, at sea level, is about 14.7 pounds per square inch. This pressure remains virtually constant on the inlet end of water seal. Obviously, a greater or lesser amount of pressure on the outlet end of the trap seal would force the water in the direction of least resistance. Since the air supplied by the vent to the outlet end provides a pressure equal to that at the inlet end of the trap, the trap seal cannot escape through siphonage.

All vent systems should be provided with a main vent and a main soil and waste vent. A MAIN VENT may be defined as a vertical length of pipe which connects fixture vents to the main soil and waste vent. (See fig. 4-16).

The MAIN SOIL AND WASTE STACK, as indicated in figure 4-16, is installed in a vertical position.

The term MAIN SOIL AND WASTE VENT refers to the portion of the stack which extends above the highest fixture branch. Note in figure 4-16 that this vent extends through the roof. Actually, it is an extension of the main soil and waste stack.

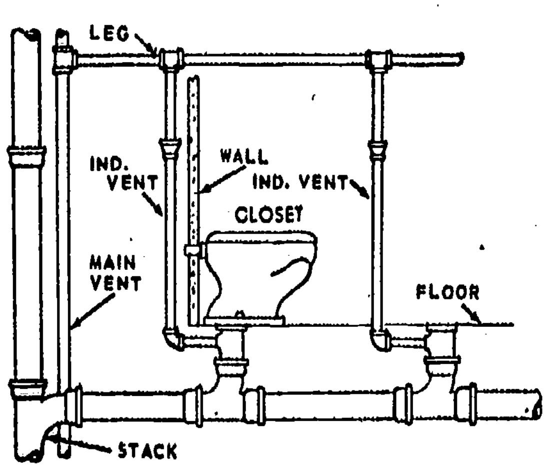


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Figure 4-17. — Individual (or back) venting.

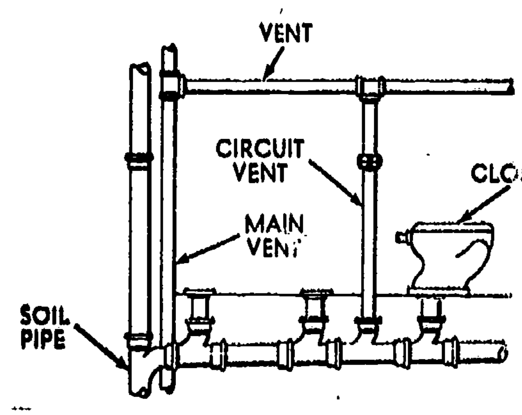

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Figure 4-19. — Water closets circuit vented.

Common Types

Various types of vents are used in the ventilation of fixtures; even in the best of installations you may find several different types of vents. The selection of a particular type depends largely on the manner in which the plumbing fixtures are to be located and grouped. Some of the common types of vents which you may use frequently in your work are mentioned briefly below.

A BACK VENT, also known as an INDIVIDUAL VENT, is a vent which connects the main vent with the individual trap underneath or behind a fixture. This method of venting is illustrated in figure 4-17. When installing two or more fixtures on the individual vent basis, it is important that the leg (see illustration) connecting the individual vents to the main vent be of sufficient size to carry the total load.

A UNIT VENT is used to vent two traps to a single vent pipe, as shown in figure 4-18. The unit vent can be used when a pair of lavatories are installed side-by-side, as well as when hung back-to-back on either side of a partition (as shown in illustration). A point to note is that the waste from both fixtures discharges into a double sanitary tee (as shown in fig. 4-18).

A CIRCUIT (or LOOP) VENT is used to serve a group of fixtures. As indicated in figure 4-19 a circuit vent extends from the main vent to a position on the horizontal branch between the last 2 fixture connections. Make sure that not more than 8 fixtures are put on any one circuit. If you have more than 8 fixtures to be circuit vented, use 2 circuits instead of one. In this type of vent, water and waste discharged by the last fixture will tend to scour the vents of other fixtures on the line.

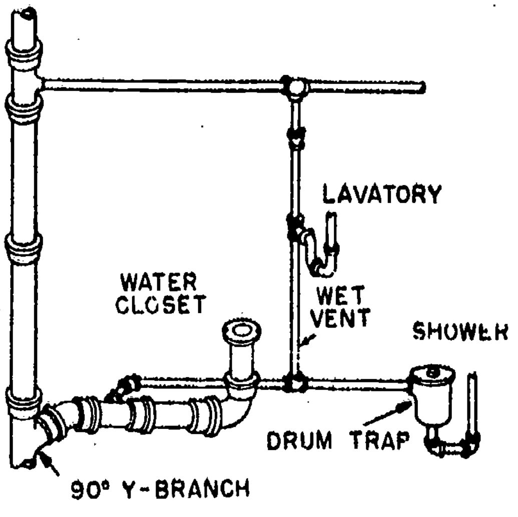

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Figure 4-20. —Wet vent.

A vent pipe in which liquid wastes flow through a portion of it is known as a WET VENT. This type may be used on a small group of bathroom fixtures, such as a lavatory, water closet, and shower, as illustrated in figure 4-20. The pipe for wet vent installation should be sized to take care of the lavatory, water closet, and shower; it should never be under 2 inches in diameter. As indicated in figure 4-20 the lavatory should be individually vented. This is necessary to prevent loss of the trap seal through indirect siphonage. Another point to note in connection with the lavatory is that the relatively clean water discharged from it will tend to scour the wet vent, in that way preventing an excessive buildup of waste material in the vent.

Installation Pointers

A venting system must be properly installed if it is to serve its intended purpose and require a minimum of repair and upkeep. This section will give you some important pointers that should prove useful in duties involving the installation of vent systems.

Referring again to figure 4-16, notice that a MAIN VENT TEE is used to form a junction between the main vent and the main soil and waste vent. This is a tapped tee, having a stack side outlet. It should be installed by calking in the vertical stack, at least 6 inches above the overflow level of the highest fixture connected. After this has been done, the vertical stack should be extended, full size or larger, through the roof to form the vent terminal. The pipe must extend at least 6 inches above the roof.

The opening in the roof through which the main soil and waste vent runs must be properly waterproofed. Roof flashing is used for this purpose. A roof flashing is a specially constructed device which, ordinarily, is made of galvanized iron or copper. Flashing is available in different sizes. The size of flashing needed for a particular job is determined by the size of the main soil and waste vent.

When installing the roof flashing on a shingled roof, extend it under two courses of shingles above the pipe. On a flat roof, place it between layers of the roofing material and have the finishing layer over the top of the flashing. To complete the installation on either type roof, always apply a coat of roofing cement as added protection against leakage.

In freezing climates, suitable provision must be made to prevent closure of the main soil and waste vent at the roof outlet by freezing. We might explain here that the air discharged by the main stack and waste vent is very humid, in which case condensation occurs. Unless proper precautions are taken, this condensation will freeze if exposed to extremely low temperatures.

One method by which you can prevent this from happening is to increase the pipe to a size or two larger than the vertical vent passing through the roof.

Another method involves the installation of a high lead flashing which will provide an insulating pocket of air between the flashing and the end of the main soil and waste vent above the roof. Being open to the heat of the building, the air pocket makes possible an intermediate warming area for gases leaving the main soil and waste vent.

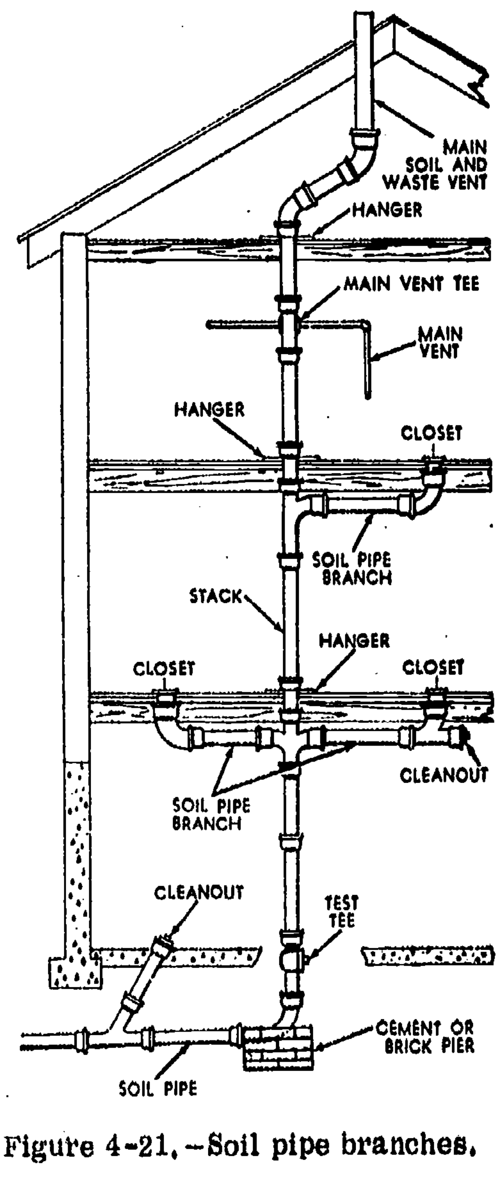

Figure 4-21. — Soil pipe branches. 54.44

Materials used in vent piping ordinarily include galvanized pipe, cast-iron soil pipe, and at times, brass, copper, and plastic piping. Asbestos-cement pipe can also be used for venting soil and waste pipe. A single length of this pipe is often sufficient for venting a stack. For such an installation, pipe is available with a machined end. This end is placed in the bell of the soil or waste pipe, and the connection made by yarning, leading, and calking.

In all phases of the venting system, the use of proper-sized piping is an important consideration. A good point to remember is that the diameter of the vent stack or main vent must be not less than 2 inches. The actual diameter depends on the developed length of the vent stack and on the number of fixture units installed on the soil or waste stack. The diameter of a stack vent should be at least as large as that of the soil or waste stack.

Soil and waste pipe BRANCHES are horizontal branch takeoffs which are used to connect various fixtures and the vertical stack. (See fig. 4-21.) One method of installing a branch takeoff from the vertical stack is by using a Y-branch with a 1/8th bend calked into it. Another method is by using a sanitary tee, which is an extra-short-pattern 90° Y-branch. Of these two methods, preference usually is given to the sanitary tee. The reason is that by using the sanitary tee you eliminate one fitting and an extra calked joint, which are required for the 1/8th bend takeoff. We might add that under some local codes you may be permitted to connect more fixture units to a given size stack when a combination Y and 1/8th bend are used. In such a case, the combination Y and 1/8th bend may be more desirable than the sanitary tee. Once either fitting is calked into place, however, the horizontal branch can be extended as necessary with lengths of soil pipe. They, too, are joined by calking.

Waste pipes should be graded downward to ensure complete draining. Horizontal vents should be pitched slightly to facilitate drainage of condensate.

In this chapter we have only covered the very basic types of vents and where they are used. However, there are many forms of ventilation which can be applied to the plumbing installation. The types used on a project will be determined largely by the manner in which the plumbing fixtures are to be installed and where located.

The importance of vents cannot be overemphasized, as this is the science of plumbing.

Anyone can join and install piping for a plumbing system, but if it is incapable of carrying away the waste it is useless. Therefore, a thorough knowledge of vents is essential.

WATER SERVICE

The water supply system for a building consists of the service pipe, distributing pipes, and necessary connecting pipes, as well as fittings and control valves. It is important that water carried by the system meets accepted standards of purity. Two major functions of a water distribution system are (1) to carry potable water for domestic use, and (2) to provide high rates of flow for firefighting purposes.

TRENCHING

The method of trenching for waterlines is similar in nature to that described earlier for sewerlines. In trenching for waterlines, though, it is not necessary to set batter boards since great care is not required in laying water pipes to grade as the water is under pressure. The pipes in a waterline may follow the contour of the earth's surface in a trench at least 2 feet deep. This should, however, be the minimum depth in which they are installed. Minimum depth of the ditch will depend upon the depth of the frostline in your area. The trench should be wide enough to permit ease of working around the pipes, and to allow the placing of the earth during backfilling. Usually, the trench will not be deep enough to require bracing.

It is advisable to locate the trench at least 4 feet from a previously dug ditch or trench; this will help prevent cave-ins. Water pipes should be laid above and 10 feet away from nearby sewers. This will help prevent the water distribution system from becoming polluted by leaks. Sometimes the water main and sewerlines may cross each other. In such cases, the water pipe must cross over the top of the sewerline, and special care must be taken to make all joints tight. However, check the local specifications prior to installing them in this manner.

The distribution system must be kept free from pollution caused by leaks, back-siphonage from faulty plumbing, and cross-connections. The greatest hazard in the distribution system is the cross-connection. This is a physical connection to another and unsafe or doubtful source of water, or a condition that will permit waste water to enter the potable public supply.

PIPING MATERIALS

Piping materials used in water supply systems include cast-iron pressure pipe, galvanized wrought iron, steel, copper, plastics, and asbestos-cement. Some of the main characteristics of pipe made from these materials are presented below.

Cast-Iron Pressure Pipe (for Water Mains)

The cast-iron pipe used for water distribution systems is somewhat different than that used for waste systems. Some of the major differences are seen in the length of the pipe, joints, and lining. Cast-iron soil pipe used for waste, as you know, comes in 5-foot and 10-foot lengths. Cast-iron pressure pipe used for water mains, however, comes in lengths of 20 feet, with either bell-and-spigot or mechanical (gland-type) joints being the most common. This pipe also comes coated with coal-tar pitch or cement-lined; however, uncoated pipe is available if needed for other purposes.

MEASURING AND CUTTING. — Cast-iron pressure pipe is measured by the inside diameter; a rule or tape frequently is used for measuring. Where a cement lining is used, though, allowance is made for the fact that the lining encroaches on the inside diameter of the pipe.

To cut cast-iron water pipe to the desired length, either a hand-operated chain cutter or a power hacksaw may be used. Due to the construction of this pipe, it does not need reaming after cutting; but, you can use a file to dress down the cut, when necessary.

FITTINGS. — Three major types of fittings used for joining cast-iron pipes in water service are tees, elbows, and couplings. Since these are similar in appearance to those used for sewer lines, a detailed description need not be given here.

JOINING. — In water service lines, bell-and-spigot cast-iron pipe is joined with lead, lead wool, or sometimes a sulfur compound. Specially prepared treated paper or asbestos rope may be used.

As the first step in making a joint, check each length of pipe to make sure it has no cracks or splits. After a careful visual inspection, a further check should be made by rapping lightly on the pipe with a hammer.

With a little experience, you will find that the presence of cracks in the hub and pipe can be determined by a difference between the ring heard when a good or a cracked length of pipe is rapped gently with the hammer.

The next step in making the joint is wrapping the yarn around the spigot end, placing it in the bell of the previously laid length, and straightening and adjusting by means of a yarning iron. Sufficient yarn should then be used to fill the joint within approximately 2 inches of the face of the bell. A joint runner is then clamped in place around the joint so that it fits tightly against the outer edge of the bell. Asbestos can be used to make a tight contact between the runner and the pipe so that the hot lead will not run out of the joint space. The lead is then poured into the V-shaped opening left at the top by the clamped joint runner. This lead fills the space between the yarn and the runner. This joint must be made in one pouring for best results. After the lead has hardened (this will take about 10 seconds), the runner is removed, and the lead, which shrinks while cooling, is expanded by calking until it makes a tight fit. Calking requires skill; too heavy blows could split the bell, or too light blows could leave the joint loose.

Lead wool, which is lead in a shredded form that does not require melting, is sometimes used when water is encountered in the trench. In this process more yarn is used, the joint being filled to about 1 inch of the face of the bell. Lead wool will require more time in calking than poured lead.

A sulfur compound is melted on the job, like lead, but at a lower temperature. It is then poured into a joint prepared as for a cast-lead joint. The primary advantage is its light weight, plus it requires no calking and gives strong joints that are not likely to blow out. Joints of sulfur compounds leak or "sweat" slightly at first but tighten up in a short time. Since the joints are rigid, they should not be used to connect a newly laid line to an old one, as the settlement of the new line will cause a broken place. A lead joint should be used at the connection.

Mechanical joints are made with rubber sealing rings held in place by metal follower rings which are bolted to the pipe. These are designed to permit expansion and contraction of the pipe without injury to the joints.

Copper Pipe and Tubing

Copper pipe and tubing with soldered joints or flared-tube connectors are being used more extensively for water service now than in the past. Copper is highly regarded because of its corrosion-resistant properties, flexibility, ease of installation, and low resistance to flow throughout its useful life.

Three types of copper, designated as type K, L, and M, are commonly used. Type K is used for underground service and general plumbing purposes; type L for general plumbing purposes; and type M with soldered fittings only. Types K and L copper come in either straight 20 foot lengths of hard temper, or in coils of 50 to 100 feet, soft temper. Type M comes in straight 20 foot lengths, hard drawn only.

Another type of copper, type DWV (drain, waste, and vent), is used only in aboveground soil, waste and vent lines. It is furnished in hard temper only and in sizes from 1 1/4 to 8 inches. It is available in 12 foot lengths as well as the standard 20 foot length.

The process used to soften copper is called annealing. The word "anneal" means to soften thoroughly and render less brittle. Copper is unlike steel in many respects. For example, when you repeatedly bend steel it becomes soft and eventually will break. With copper, repeated bending or excessive increasing and decreasing of pressure or vibration will make the tubing brittle and stiff, to the point where it will break if it is forced to bend.

To soften steel, it is heated to a cherry red color and cooled very slowly. The slower it is

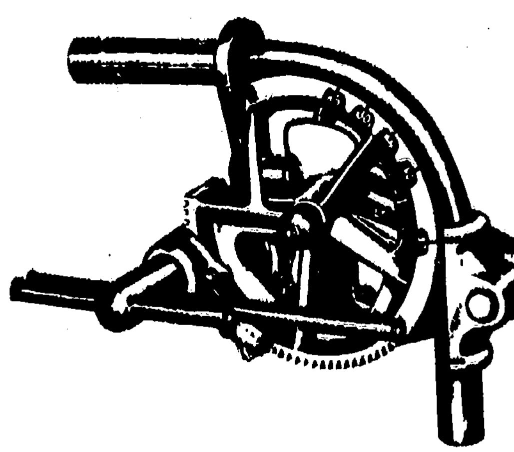

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Figure 4-22. — Portable copper pipe and tube bender.

cooled, the softer the steel becomes. With copper, the opposite is true. Copper is heated uniformly to a dull red color and then quenched (dipped) in water (for water service). The faster it is cooled, the softer the copper becomes.

BENDING COPPER.—Copper, properly annealed, can be bent by hand when sharp bends are not desired. Copper will partially collapse during the bending process if a tube bender is not used, or if the copper is not filled with some kind of easily removable material such as sand. Simple bends can also be made by wrapping the outside of the copper tightly with soft wire and bending the copper by hand. However, if a line must make a 45° or 90° bend, you should use a tube bender. Hand tube benders are available in corresponding sizes for each size of copper. These benders will assist you to make neat, accurate bends easily, quickly, and without marring the copper or restricting the flow through the copper. It is easy to make a bend, but difficult to get the bend in the correct location on the copper and to the correct degree. Be certain that you have the correct size bender for the copper which you intend to bend. A bender that is either too small

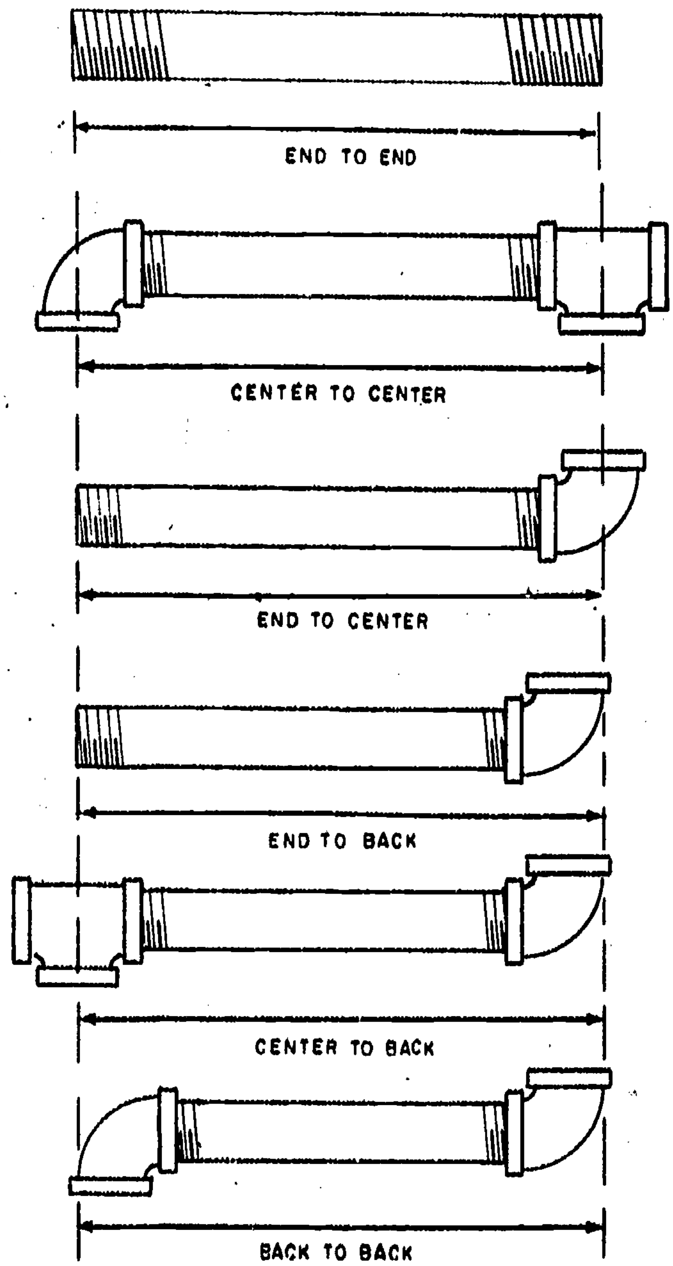

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Figure 4-23.—Methods of measuring pipe and tubing.

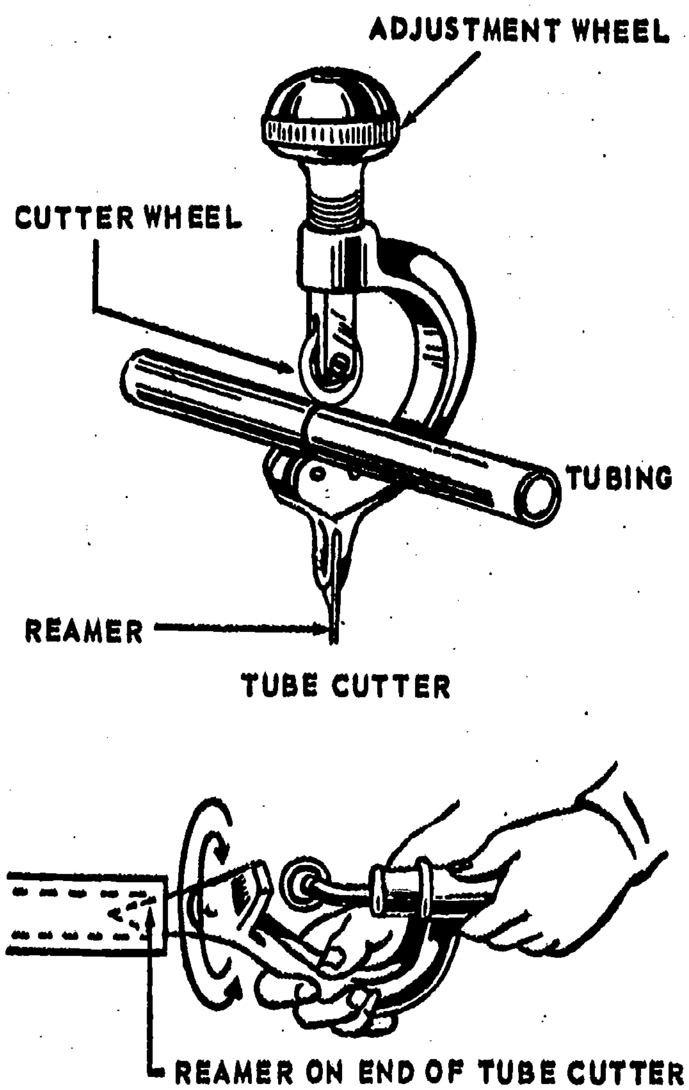

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Figure 4-24.—Cutting and reaming copper.

or too large for the copper will make a faulty bend. Figure 4-22 illustrates one type of pipe bender used to bend copper.

MEASURING. — Six methods are commonly used in measuring copper pipe or tubing. They are: (1) end to end; (2) center to center; (3) end to center; (4) end to back; (5) center to back; and (6) back to back. These measurements are also commonly used in measuring threaded galvanized or black iron pipe. The measurements are generally made with a rule.

Each of the six methods mentioned above is explained below, and each is illustrated in figure 4-23.

END TO END indicates a pipe that is threaded on both ends. The measurement is from one end of the pipe to the other end, including both threads.

CENTER TO CENTER means that there is a fitting on each end of the pipe and the measurement is made from the center of the fitting on one end to the center of the fitting on the other end.

The END TO CENTER method applies to pipe having a fitting on one end. The measurement is made from the end of the pipe to the center of the fitting.

END TO BACK also refers to pipe with a fitting on one end only. But the measurement here is from the back of the fitting to the other end of the pipe.

CENTER TO BACK indicates a pipe with a fitting on each end. The measurement, in this case, is taken from the center of one fitting to the back of the other fitting.

A BACK TO BACK measurement refers to pipe with a fitting on each end. Here the measurement is from the back of one fitting to the back of the other fitting.

CUTTING AND REAMING. — Copper should be cut with a tube cutter, where available. Mark the copper where it is to be cut and install the cutter so that the cutter wheel is over the mark as shown in figure 4-24. Now turn the tube cutter knob or handle clockwise in order to force the cutter wheel against the copper. Continue revolving the cutter, and turning the cutter knob slightly after each revolution, until the copper is cut through and separates.

Copper may be cut with a hacksaw, although a tube cutter is preferable. However, care must be exercised to cut the copper square if it is to be flared. Be sure to use a fine-toothed hacksaw blade, 32 teeth per inch, when cutting copper.

After the copper is cut, the burr inside the cut must be removed. This is done with the reamer on the tube cutter. Place the reamer in the end of the copper, and revolve the tube cutter clockwise until the burr is removed.

JOINING. — In working with copper you will use both flared and sweated types of joints. Flaring is a method of forming the end of the copper into a funnel shape so that it can be held in a threaded fitting when making a line joint. Before a flare is made, slip a flare nut on the copper. A common error is to forget to put the nut on before making the flare. Figure 4-25 shows a few typical copper fittings. For additional information on making flared connections, refer to <u>Tools and Their Uses</u>, NavPers 10085-B.

A sweated joint is made with solder instead of threads or flares. When making a soldered joint using a sweat fitting, clean an inch or more of the end of the copper tube with steel wool or 000 sandpaper until new metal shows. Clean inside of the fitting in the same manner. Spread a thin film of paste flux on the tube end with a clean brush or applicator. Do not apply paste with the finger or an oily applicator.

Carefully insert the copper into the fitting to make them fit together very closely. Capillary action must spread the solder evenly and completely over the surfaces, but will not be effective with loose fits because of excess clearance. Should the fit be loose you will probably have to tin the end of the copper tube. Tinning is the process of applying a small amount of solder to the end of the copper before it is inserted into the sweat fitting.

Heat is applied directly to the metal with a flame. Various types of heat-generating equipment are available. In your work, however, you will generally use oxyacetylene or methylacetylene propadiene (MAPP) cutting/welding equipment or a Presto-lite heating unit.

The Presto-lite torch is ideal for soft soldering, because it delivers a small controllable

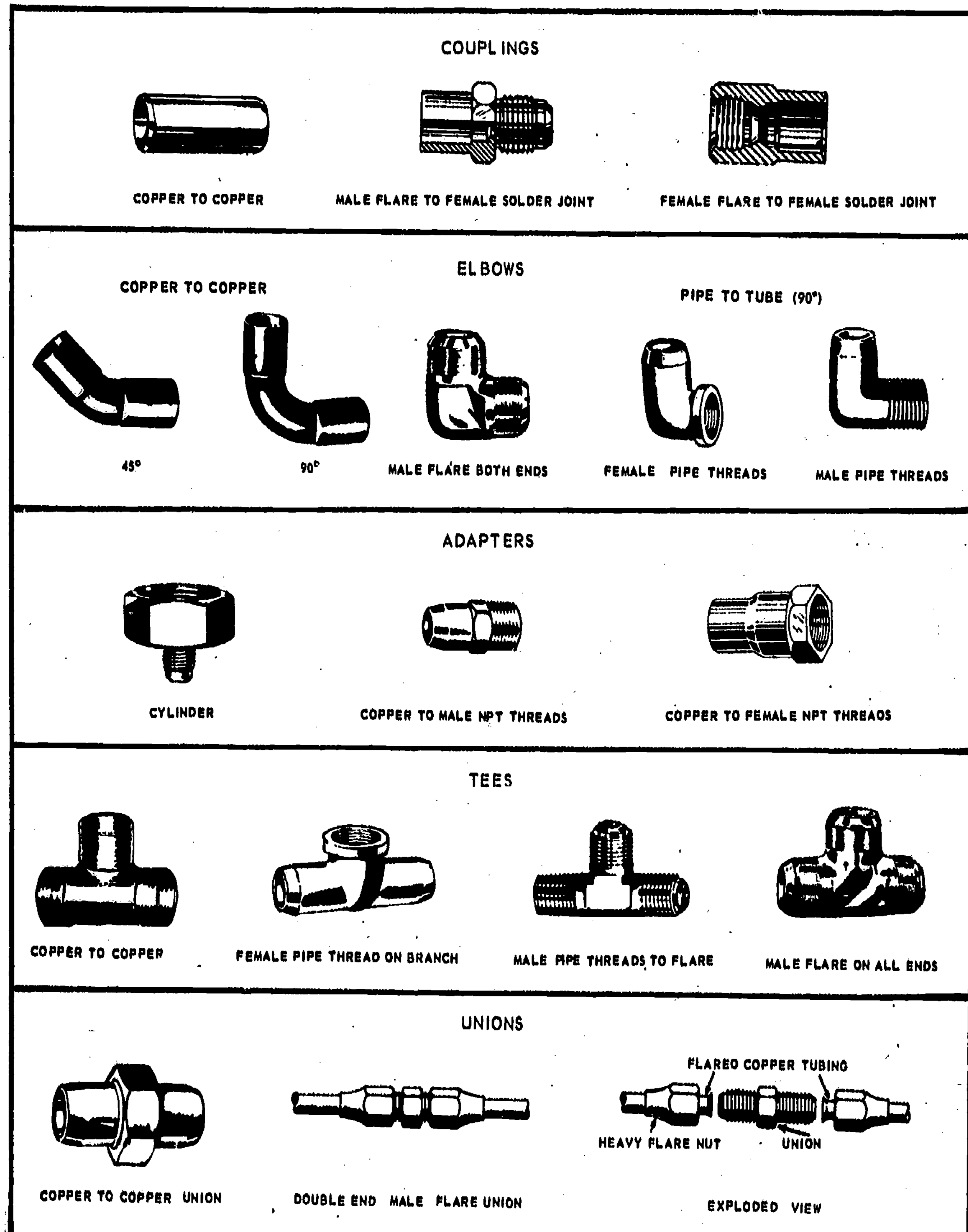

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Figure 4-25. — Typical copper fittings.

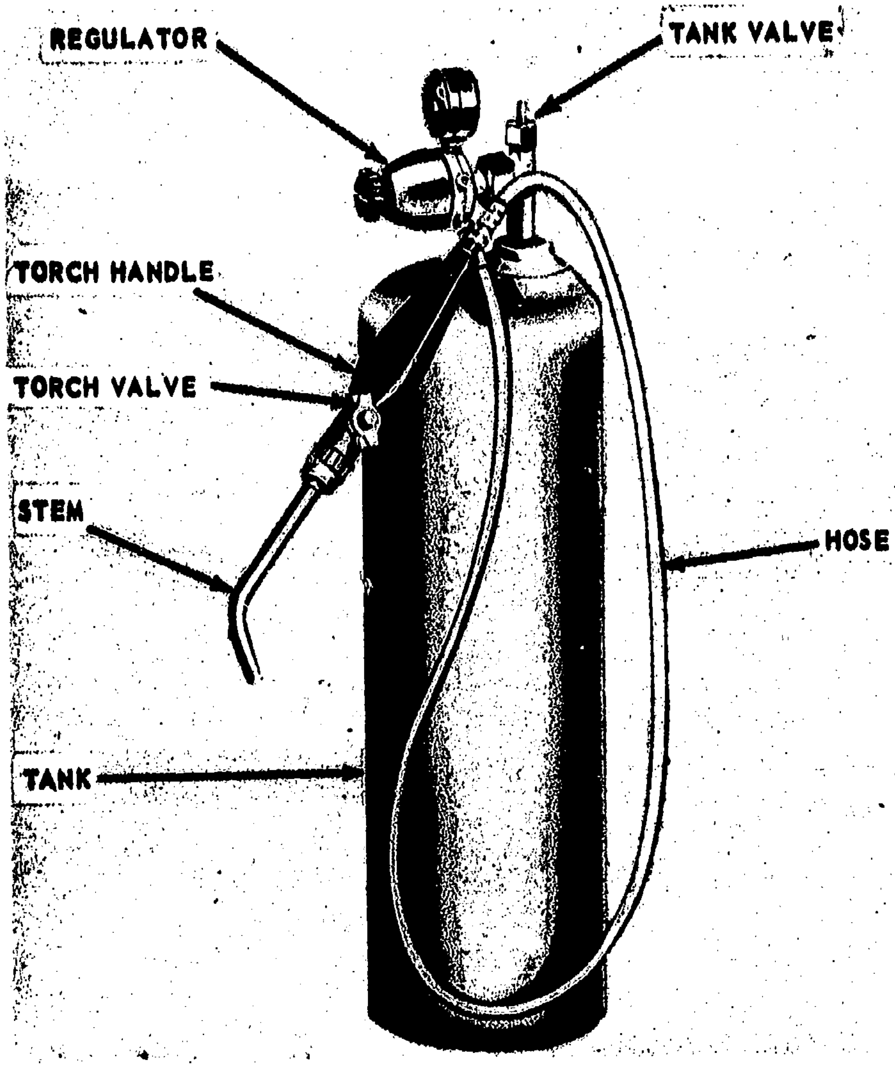

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Figure 4-26. — Presto-lite heating unit.

flame. The Presto-lite unit consists of a small acetylene cylinder, regulator, rubber hose, torch, and two or more removable tips. This unit burns acetylene gas as a fuel in the presence of oxygen. Figure 4-26 will give you an idea of what the Presto-lite unit looks like.

When heating, apply heat to the fitting or thickest part until it reaches the melting temperature of the solder. Feed the solder at the edge of the fitting. When a continuous ring of solder appears at the end of the fitting, the joint is complete.

After soldering is complete, clean the joints with a wire brush, soap and water, or emery cloth. Exercise caution to remove all flux from the joint after it is soldered, since any flux left on a joint will cause corrosion.

SILVER BRAZING. — In plumbing operations you may occasionally be called upon to join copper pipe or tubing by silver brazing. You may also use silver brazing in making repairs to air-conditioning and refrigeration equipment, water systems, galley equipment, and so on.

SILVER BRAZING, also referred to as SILVER SOLDERING or HARD SOLDERING, is a brazing process wherein fusion is accomplished by heating with a gas flame and by using silver alloy filler metal having a melting point above 800° F, but below the melting point of the base metal. The filler metal is distributed in the joint by capillary attraction.

Since capillary attraction is important in the silver brazing process, it will be helpful to understand what is meant by this term. Perhaps the best way to understand capillary attraction is to consider some everyday examples of the process. If you put one end of a strip of cloth in a glass of water and allow the other end to hang over the edge of the glass, the end of the cloth which is not in the water will become wet. Water rises in the cloth by capillary attraction. When you use a blotter, the ink is drawn up into the blotter by capillary attraction. The wick on an oil lamp can be lit because the oil rises in the wick by capillary attraction. In each of these examples, we have a LIQUID (water, ink, oil) which moves into an opening in a SOLID (cloth, blotter, wick) by the process called capillary attraction. A basic rule of capillary attraction is that the distance the liquid will be drawn into the opening in the joint depends on the size of the opening in the joint; the smaller the opening, the farther the liquid will be drawn in.

In just the same way, capillary attraction causes the melted filler metal used in silver brazing to be drawn into the narrow clearance between the joining members. Capillary attraction will not work unless the filler metal is MELTED and unless the size of the opening is quite small. Therefore, the application of heat and the use of a very small clearance between joining members are essential to the silver brazing process. The heat is necessary in order to melt the filler metal and to keep it molten; the small clearance is necessary to allow capillary attraction to draw the molten metal into the space between the joint members.

Equipment.—A number of different types of equipment are used in silver brazing. In your work, silver brazing will probably be accomplished by use of oxyacetylene or methylacetylene propadiene (MAPP) cutting/welding equipment.

The equipment needed for silver brazing with oxyacetylene cutting/welding equipment includes a cylinder of acetylene, a cylinder of oxygen, two regulators, two lengths of hose with fittings, and a welding torch with tips (see fig. 4-27).

Acetylene regulators, hoses, torches, and welding tips are used with MAPP gas. The only equipment changes recommended are the use of MAPP cutting tips and heating heads to obtain maximum results. Cutting tips and heating heads designed for acetylene can safely be used with MAPP, but lighting problems and increased preheating and cutting times will probably occur.

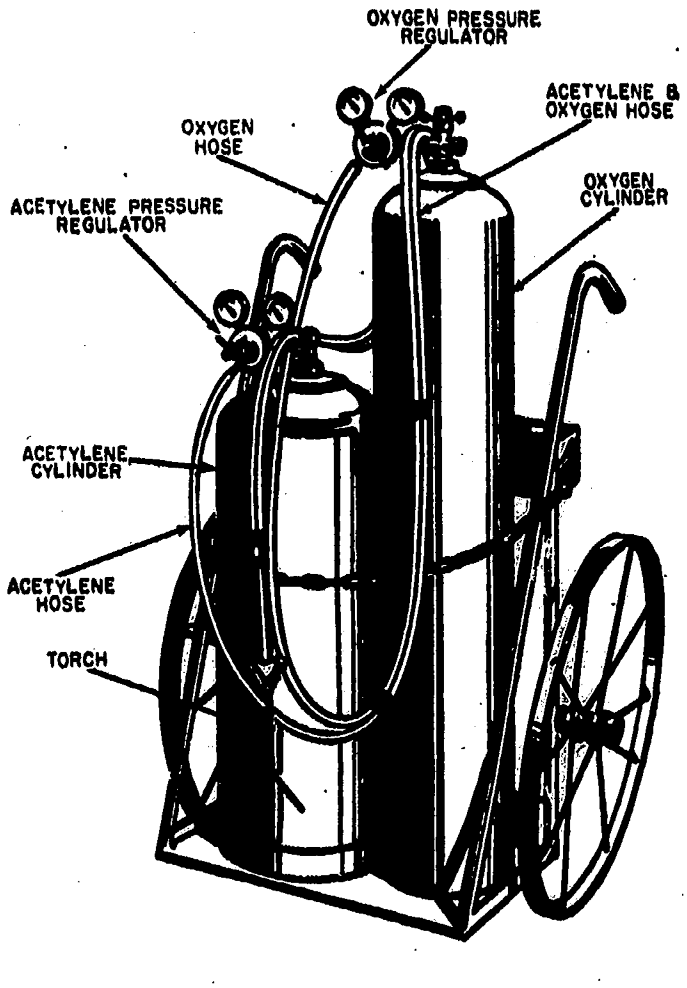

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Figure 4-27.—Portable oxyacetylene outfit.

Setting Up Equipment.—When silver soldering is to be done, it is important that the equipment be set up properly before lighting the torch. The procedure for setting up oxyacetylene cutting/welding equipment is given below. If you are familiar with the procedure for setting up oxyacetylene cutting/welding equipment, you should have no difficulty making the equipment changes necessary for silver brazing with MAPP gas.

1. Secure the cylinders so that they cannot be upset. Remove the protecting caps.

2. Crack the cylinder valves slightly to blow out any dirt that may be in the valves. Close the valves and wipe the connections with a clean cloth.

3. Connect the acetylene pressure regulator to the acetylene cylinder and the oxygen pressure regulator to the oxygen cylinder. Using the

wrench provided with the equipment, tighten the connecting nuts.

4. Connect the red hose to the acetylene regulator and the green hose to the oxygen regulator. Tighten the connecting nuts enough to prevent leakage.

5. Back off on the regulator screws, and then open the cylinder valves slowly. Open the acetylene valve 1/4 to 1/2 turn. This will allow an adequate flow of acetylene and the valve can be turned off quickly in an emergency. (NEVER open the acetylene cylinder valve more than 1 1/2 turns.) The oxygen cylinder valve should be opened all the way to eliminate leakage around the stem. (Oxygen valves are double seated or have diaphragms to prevent leakage when open.) Read the high pressure gage to check the pressure of each cylinder.

6. Blow out the oxygen hose by turning the regulator screw in and then back out again. If it is necessary to blow out the acetylene hose, do it ONLY in a well ventilated place that is free from sparks, flames, or other possible sources of ignition.

7. Connect the hoses to the torch. Connect the red acetylene hose to the connection gland that has the needle valve marked AC or ACET. Connect the green oxygen hose to the connection gland that has the needle valve marked OX. Test all hose connections for leaks by turning both regulator screws IN, while the needle valves are closed. Then turn the regulator screws OUT and drain the hose by opening the needle valves.

8. Adjust the tip. Screw the tip into the mixing head and assemble in the torch body. Tighten by hand and adjust to the proper angle. Secure this adjustment by tightening with the wrench provided with the torch.

9. Adjust the working pressures. The acetylene pressure is adjusted by opening the acetylene torch needle valve and turning the regulator screw to the right. Adjust the acetylene regulator to the required working pressure for the particular tip size. (Acetylene pressure should never exceed 15 psig.)

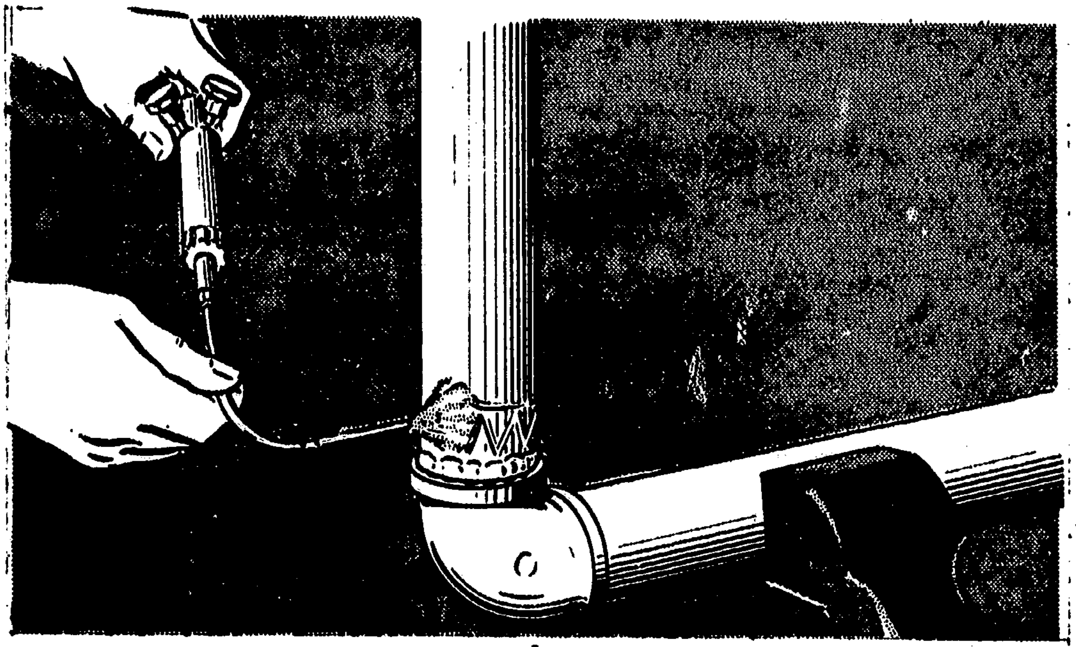
10. Light and adjust the torch flame. Open the acetylene needle valve on the torch and light the acetylene with the spark lighter. Keep your hand out of the way. Adjust the acetylene valve until the flame just leaves the tip face. Open and adjust the oxygen valve until you get the proper flame.

Filler Metal.—Silver-base alloys are commonly used as filler metal for brazing. Although filler metals other than silver-base alloys are often employed, the technique for making a brazed joint is basically the same. A main difference is the amount of heat necessary to melt the filler metal, which in all instances is below the melting point of the base metals. Silver brazed joints have high strength on ferrous and nonferrous metals. The strength of a properly made joint will exceed that of the metals joined. On stainless steels it is possible to develop a joint tensile strength of approximately 130,000 psi. Since brazing with silver-base alloys is typical of brazing generally, we are especially interested here in the use of these materials as filler metal. What is said, though, applies equally to brazing with other filler metals that are distributed by capillary attraction.

Methods of Silver Brazing.—Two methods are used to make joints between tubes and fittings in piping systems with silver-base brazing filler metal: the INSERT method, and the FEED-IN method. With either method, the parts must be adequately supported during heating. It is also important that the work be held firmly in position until the brazing filler metal has completely solidified.

When using the INSERT method, a strip of the silver-base filler metal is inserted in the joint prior to assembly. Before brazing the parts, clean them with emery cloth, steel wool, or an accepted cleaning solvent. Apply flux with a brush. Next, fit the two parts together and align them. Then light off the torch and direct the heat on the tube or thinner portion as shown in view A of figure 4-28. The lines drawn on the tube indicate the path of the torch while heating the tube.

Heat applied to the tubing causes it to swell and bring the surface of the tube into contact with the inside surface of the fitting. This closes the clearance area, forcing the flux from either end of the joint. Be sure to heat the entire circumference of the tube until flux begins to flow. Flux flow tells you that the tube has expanded sufficiently and is the signal to proceed to the second phase of heating. As soon as the flux flows freely—about 6 seconds after fluidity becomes apparent—direct the flame to that portion of the fitting hub farthest from the junction of the tube and the fitting. Rotate



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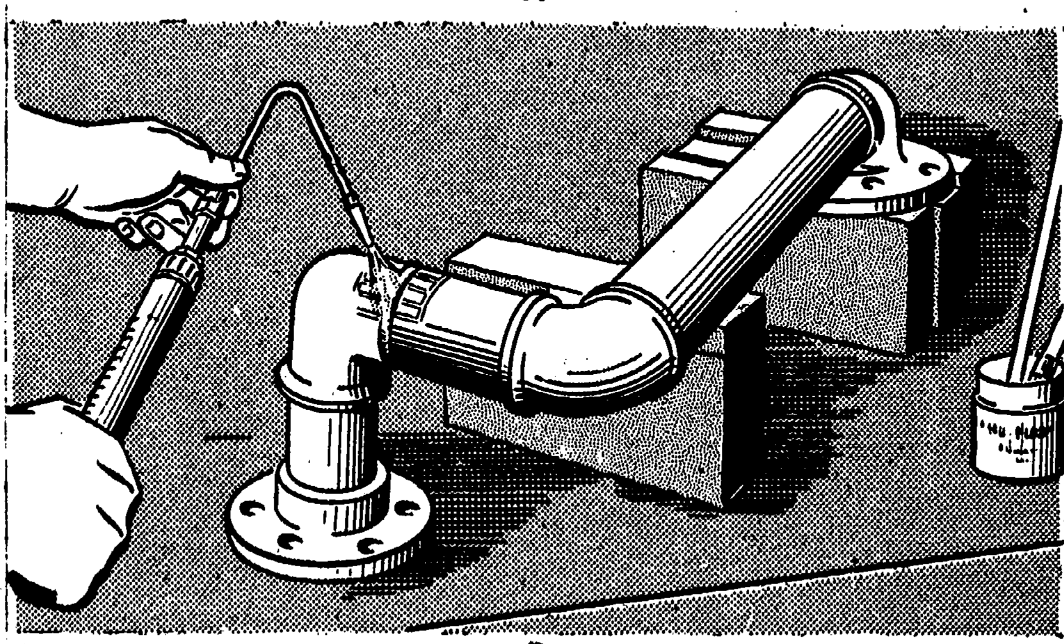

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Figure 4-28.—Applying heat for brazing a tube and fitting.

the flame over the joint segment until brazing filler metal appears at the junction of the pipe and fitting. At that moment, flick the torch away so that the flame wipes toward the pipe. This completes one segment of the joint. The procedure is repeated until all segments are completed. A satisfactory joint shows a continuous ring of filler metal at the end of the fitting. The ring must be smooth and concave.

Extinguishing Flame and Securing Equipment.—To extinguish the oxyacetylene flame and to secure equipment after completing a job, or when work is to be interrupted temporarily, take the following steps:

1. Close the acetylene needle valve first, then close the oxygen needle valve. This extinguishes the flame.

2. Close both oxygen and acetylene cylinder valves. Leave the oxygen and acetylene regulators open temporarily.

3. Open the acetylene needle valve on the torch and allow gas in the hose to escape (5-15 seconds) to the outside atmosphere. Do not allow gas to escape into a small or closed compartment. Close the acetylene needle valve.

4. Open the oxygen needle valve on the torch and allow gas in the hose to escape (5-15 seconds). Close the valve.

5. Close both oxygen and acetylene cylinder-regulators by backing out the adjusting screws until they are loose.

Follow the above procedure whenever work is interrupted for an indefinite period. If work is to stop for only a few minutes, securing cylinder valves and draining the hose is not necessary. However, for any indefinite work stoppage, follow the entire extinguishing and securing procedure. For overnight work stoppage in areas other than the shop, it is safer to remove pressure regulators and torch from the system. Double check the cylinder valves to make sure they are closed securely.

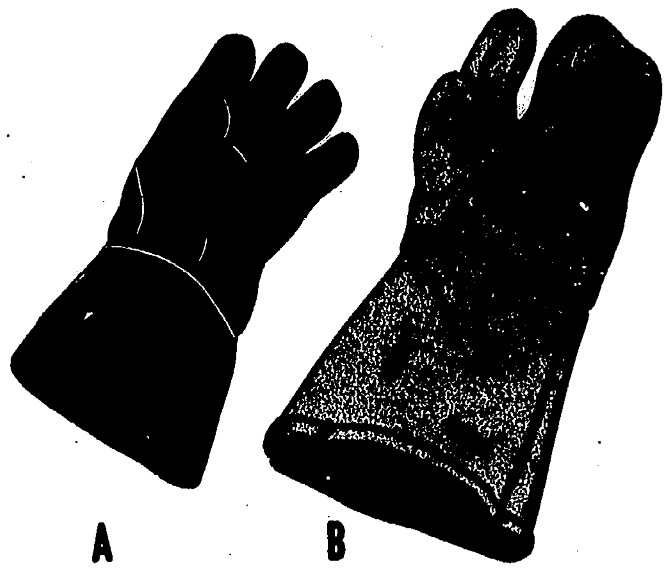

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Figure 4-30.—Gauntlet gloves and mitts.

Care of Equipment.—A common trouble with torches used in silver soldering is that the orifice in the torch tip becomes clogged with slag. When this happens, the flame will not burn properly. Inspect the tip before using the torch. If the passage is obstructed, you can clear it with wire tip cleaners of the proper diameter, or with a soft copper wire. Tips should NOT be cleaned with machinists' drills or other hard, sharp instruments. These devices may enlarge or scratch the tip opening and greatly reduce the efficiency of the torch tip.

Should the end of the torch tip become rough and pitted and the orifice become oversized (bell-mouthed), you should recondition the tip. Place a piece of emery cloth, grit side up, on a flat surface; hold the tip perpendicular to the emery cloth, and rub it back and forth just enough to true the surface and to bring the orifice back to its original diameter.

Safety.—Proper eye protection is of utmost importance, not only for the equipment operator, but also other personnel—such as helpers, chippers or inspectors—in the vicinity where soldering or silver brazing is being done. Eye protection is necessary because of hazards posed by stray flashes, reflected glare, flying sparks and globules of molten metal. Figure 4-29 shows two types of goggles used in soldering and silver brazing. One is a SPECTACLE type,

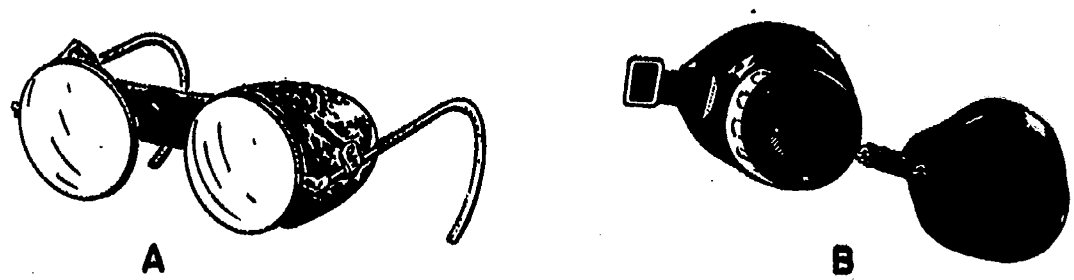

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Figure 4-29.—(A) Spectacle type of goggles. (B) Eyecup or cover type of goggles.

often referred to as FLASH GOGGLES, which is furnished with metal side shields (see view A of fig. 4-29). This type may have either a rigid, nonadjustable or adjustable metallic bridge. The other type of goggles is an EYECUP or COVER type having flexibly connected lens containers shaped to conform to the configuration of the face (see view B of fig. 4-29). This type is designed for those who wear glasses.

For hand protection, you may have to use either gauntlet gloves or mitts such as those shown in figure 4-30.

Some of the important safety precautions to be observed in working with acetylene and oxygen cylinders are given below. There are quite a number of precautions that apply to cylinders, so the following precautions should NOT be considered as a complete list of precautions to be observed.

Stow all cylinders carefully, in accordance with prescribed stowage procedures. Cylinders should be stowed in dry, well-ventilated, well-protected places, away from heat and away from combustible materials. DO NOT stow oxygen cylinders in the same compartment as acetylene or other fuel gas cylinders. All cylinders should be stowed in an upright position rather than horizontally. If acetylene cylinders are not stowed in an upright position (valves at top), they must not be used until they have been allowed to stand in an upright position for at least 12 hours to prevent acetone discharge. This tendency to discharge acetone will depend largely upon the type of porous filler, but 12 hours will be ample time regardless of the condition of the filler.

Do not allow anyone to tamper with cylinder safety devices.

Never place a cylinder in such a position that it could form part of an electrical circuit.

Never interchange hoses, regulators, or other apparatus intended for oxygen with those intended for acetylene.

Never attempt to transfer acetylene from one cylinder to another, or to refill an acetylene cylinder, or to mix any other gas with acetylene.

Keep the valves closed on empty cylinders.

Do not stand in front of cylinder valves or regulators while opening them.

When a wrench is required to open a cylinder valve, leave the wrench in place while the cylinder is being used so that the valve can be closed quickly in an emergency.

Keep oxygen cylinders and fittings away from oil and grease! Even a small amount of oil or grease may ignite violently, with explosive force, in the presence of oxygen. NEVER lubricate any part of an oxygen cylinder, valve, or fitting.

Do not drop cylinders. Do not handle them roughly. Rough handling may cause a cylinder valve to break off, and the sudden release of gas from a full cylinder may cause it to take off like a missile.

Always open cylinder valves slowly.

Close cylinder valves before moving the cylinders.

Keep a clear space between the cylinders and the work so that the cylinder valves may be reached quickly and easily if necessary.

Never use acetylene from cylinders without reducing the pressure through a suitable pressure reducing regulator. Acetylene working pressures in excess of 15 pounds per square inch must be avoided. Oxygen cylinder pressure must likewise be reduced to a suitable low pressure; high pressure may burst the hose.

In case an acetylene cylinder catches fire, if possible, try using a WET BLANKET to extinguish the fire. If this fails, spray a stream of water on the cylinder to keep it cool. Test for leaks with soapy water—not with an open flame.

Crack each cylinder valve for an instant to blow out dirt or other foreign matter before attaching pressure regulators.

Never drag, slide or roll gas cylinders on their side when moving them. If a special handling truck is not available, a good way to move a cylinder is to roll it by tilting towards you slightly, then rotating the cylinder on its bottom edge. Rough handling, dropping of cylinders, or allowing them to strike violently against each other or against other objects, can cause serious accidents, because of the nature of the gases contained.

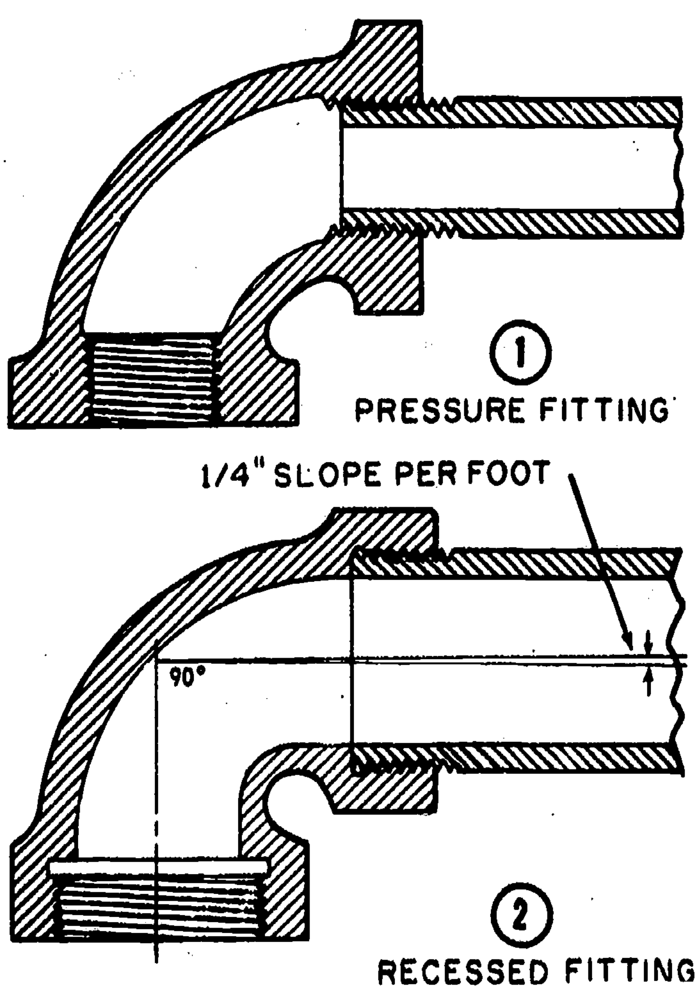
When the contents of a cylinder have been used, with a piece of soapstone or keel, crayon mark the cylinder to indicate that it is EMPTY. The letters "E" are generally used for this purpose. Stow empty cylinders separately from the charged ones. Stowage spaces must have adequate ventilation, and must not be exposed to fire hazards, extremes of weather, continuous dampness, or accumulations of snow or ice.

Galvanized Pipe

The term GALVANIZED is used to indicate how wrought-iron and steel pipe are protected in order to resist corrosion. Wrought-iron and steel pipe are both made in the same manner. But wrought iron is about twice the cost of galvanized steel; wrought iron also is used more for waste systems than for water service. Almost all steel and wrought-iron pipe are galvanized, at the factory, on both the outside and inside.

Black iron pipe (not galvanized) is normally cheaper than galvanized pipe. Black iron pipe is suitable for use in heating (both steam and hot water) and compressed air systems. It is also used for gas and oil pipe lines exclusively. Black iron pipe is NOT suitable for use, either in the supply or drainage systems, as it rusts and will cause stoppages or leaks in a relatively short time.

Galvanized wrought iron and steel pipes are cut, measured, threaded, and so on, in the same manner. Both types of pipe come in lengths from 18 to 22 feet, with about 20-foot lengths being average. These pipes are classified into weights, such as standard, heavy, and extra heavy. These terms refer to the wall thickness of the pipe, a factor which has a direct bearing on the amount of pressure the pipe will withstand.



54.48
Figure 4-31. — Comparison of pressure and recessed type fitting.

FITTINGS. — The fittings used on either wrought-iron or steel pipe are generally made of malleable or cast iron. There are two general types of iron pipe fittings, the pressure type and the recessed type. For a comparison of these two types of fittings, study figure 4-31.

The pressure type of fitting is the standard fitting used on water pipe. The recessed type fitting, also known as a cast-iron drainage or Durham fitting, is generally required on all drainage lines. The recessed type is most suitable where a smooth joint is desired: it reduces the probability of grease or foreign material remaining in the joint and causing a stoppage in the line. Recessed fittings, shown in figure 4-31, are designed so that horizontal lines entering them will have a slope of 1/4 inch per foot.

Types of iron pipe fittings include elbows, crosses, tees, and unions.

Four types of elbows used are 90°, 45°, street, and reducing elbows. The 90° elbow is used to change the direction of an iron pipe 90°, and a 45° elbow to change the direction 45°.

STREET elbows are used to change direction of an iron pipeline in a close space where it would be impossible or impracticable to use an elbow and nipple. Both 45° and 90° types of street elbows are available. Street elbows have one female and one male thread rather than two female threads.

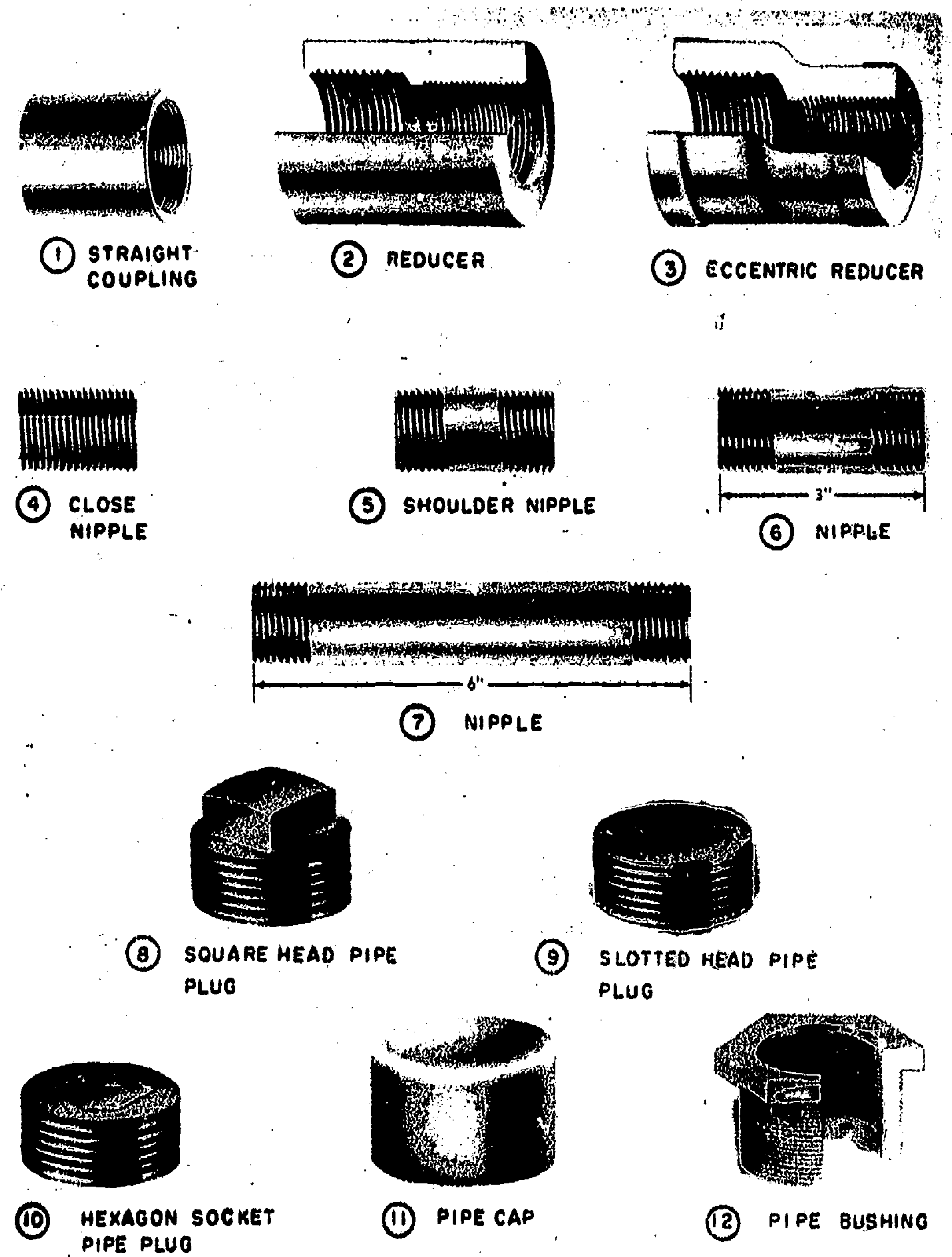
The REDUCING elbow is similar to the regular 90° elbow except that one opening is smaller than the other. For instance, a 3/4-inch pipe may be screwed into one opening of this fitting and a 1/2-inch pipe may be screwed into the other opening.

Iron pipe CROSSES are made of malleable iron in straight and reducing patterns and have female threads at all four branch points.

A common type of iron pipe tee is the STRAIGHT tee, which has a straight-through portion and a 90° takeoff on one side. All three openings of the straight tee are of the same size.

Another common type is the REDUCING tee. It is similar to the straight tee just described except that one of the threaded openings is of a different size than the others.

Two types of iron-pipe unions in general use are the ground joint union and flange union. The GROUND JOINT UNION consists of three pieces, and the FLANGE UNION is made in two parts. Both types are used for joining two



11.311(54)B

Figure 4-32. — Types of iron pipe couplings, nipples, plugs, caps, and bushings.

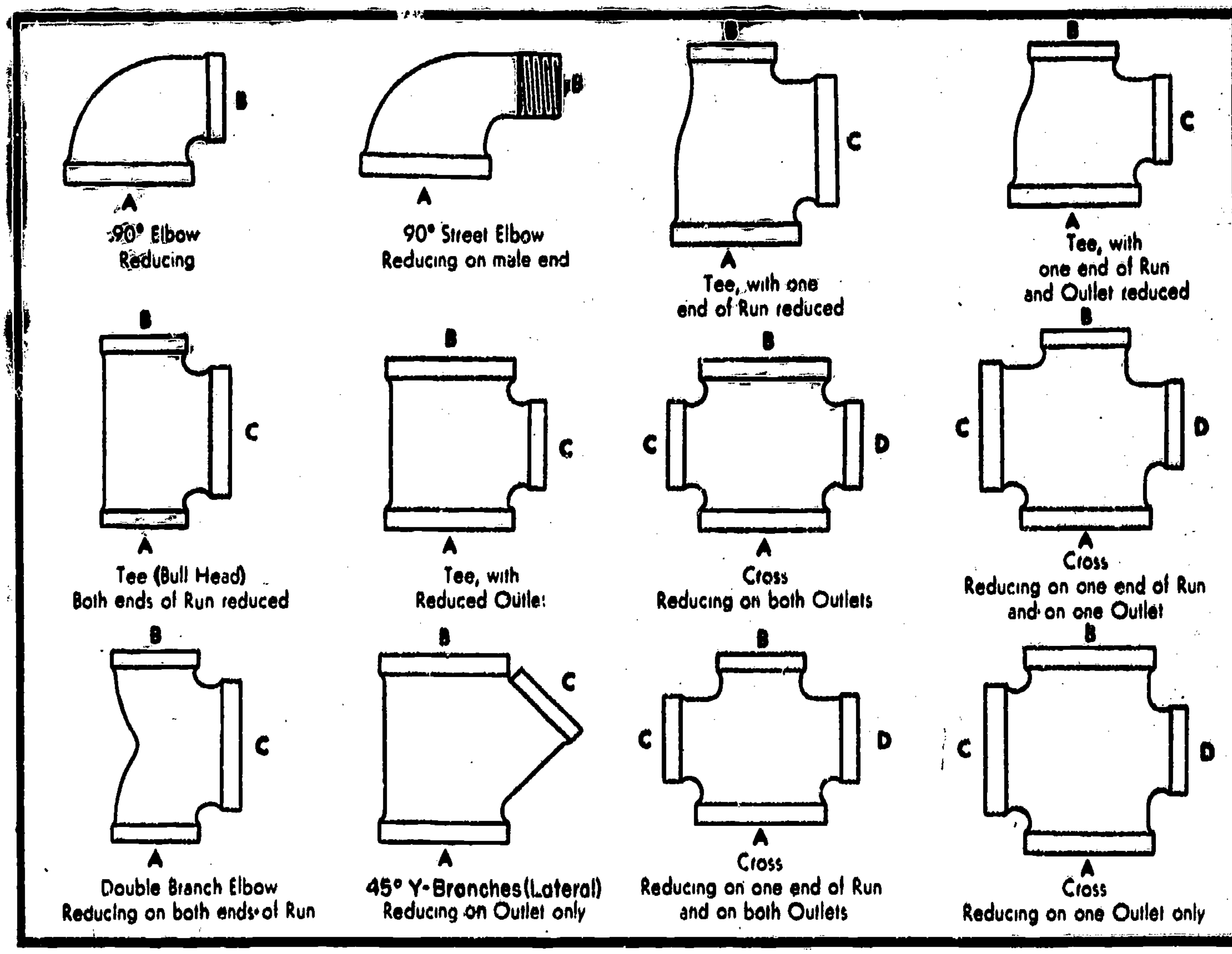
pipes together, and are so designed that they can be disconnected easily.

Other types of iron-pipe fittings, to mention a few, include couplings, nipples, pipe plugs, pipe caps, and pipe bushings. With space being limited, we can only touch briefly on these additional types.

Three common types of couplings are: straight coupling, reducer, and eccentric reducer. (See fig. 4-32.) The STRAIGHT COUPLING is used for joining two lengths of pipe in a straight run which does not require additional fittings. A REDUCER is used to join two pipes of different sizes. The ECCENTRIC REDUCER has two female threads of different sizes with different centers so that, when joined, the two pieces of pipe will not be in line with each other, but can be installed so as to provide optimum drainage of the line.

A NIPPLE is a short length of pipe (12" or less) with a male thread on each end. It is used to make an extension from a fitting. In plumbing work, nipples often are used in great quantities. Nipples are available in many precut sizes. Figure 4-32 will give you an idea of several common types of nipples.

Pipe PLUGS are fittings with male (outside) threads. They are screwed into other fittings to close openings. Pipe plugs have various types of heads, such as square, slotted, and hexagon socket (fig. 4-32.)



11.310(54)

Figure 4-33. —How to read fittings.

A pipe CAP (see fig. 4-32) is a fitting with a female (inside) thread. It is used for the same purpose as a plug except that the pipe cap screws on the male thread of a piece of pipe or nipple.

A pipe BUSHING is a specialized fitting with a male thread on the outside and a female thread on the inside. (See fig. 4-32.) Bushings may be used to reduce the size of openings of fittings and valves to a smaller diameter.

At times you may use the DIELECTRIC or INSULATING TYPE of fittings. These fittings are used to connect underground tanks or hot water tanks. They are also used when pipes of dissimilar metals are to be joined. The purpose of dielectric fittings is to curtail galvanic or electrolytic action. The most common dielectric fittings are the union, coupling, and bushing.

READING SIZE OF FITTINGS.—To assist you in reading the designations for fittings, it should be explained that each opening of the fitting is identified with a letter which indicates the sequence to be followed in reading the size of the fitting.

For example: A cross having one end of run and one outlet reduced is designated as 2 1/2(A) x 1/4(B) x 2 1/2(C) x 1 1/2(D), simply by naming the largest opening first and then naming the other openings in the order indicated. (See fig. 4-33.)

Elbows and crosses are always identified by designating first the size of the largest opening, following with the size of other openings in proper order. Tees, 45° Y-branches and double branch elbows are identified by designating the size of the largest opening on the run first, the opposite opening of the run second, and the size of the outlet last. For example: a 3 x 2 x 1 1/2 size tee is one that has openings 3(A) x 2(B) x 1 1/2(C).

In designating the outlets of side outlet reducing fittings, the size of the side outlet is named last. Refer to figure 4-33.

The same rules applying to the reading of screwed fittings also apply to reading other reduced fittings.

MEASURING.—Galvanized steel, galvanized wrought-iron, and black iron pipe are measured FOR SIZE by the nominal INSIDE diameter of the pipe. The outside diameter of the pipe will remain constant, however, for the different weights; whereas the inside diameter of the pipe will vary because of the wall thickness of the pipe. The reason for keeping the outside diameter constant is that the pipe is normally joined by threaded joints, and one die can be used to thread any weight of one size; in addition, fittings of a uniform size on the inside will fit all the different weights of pipe.

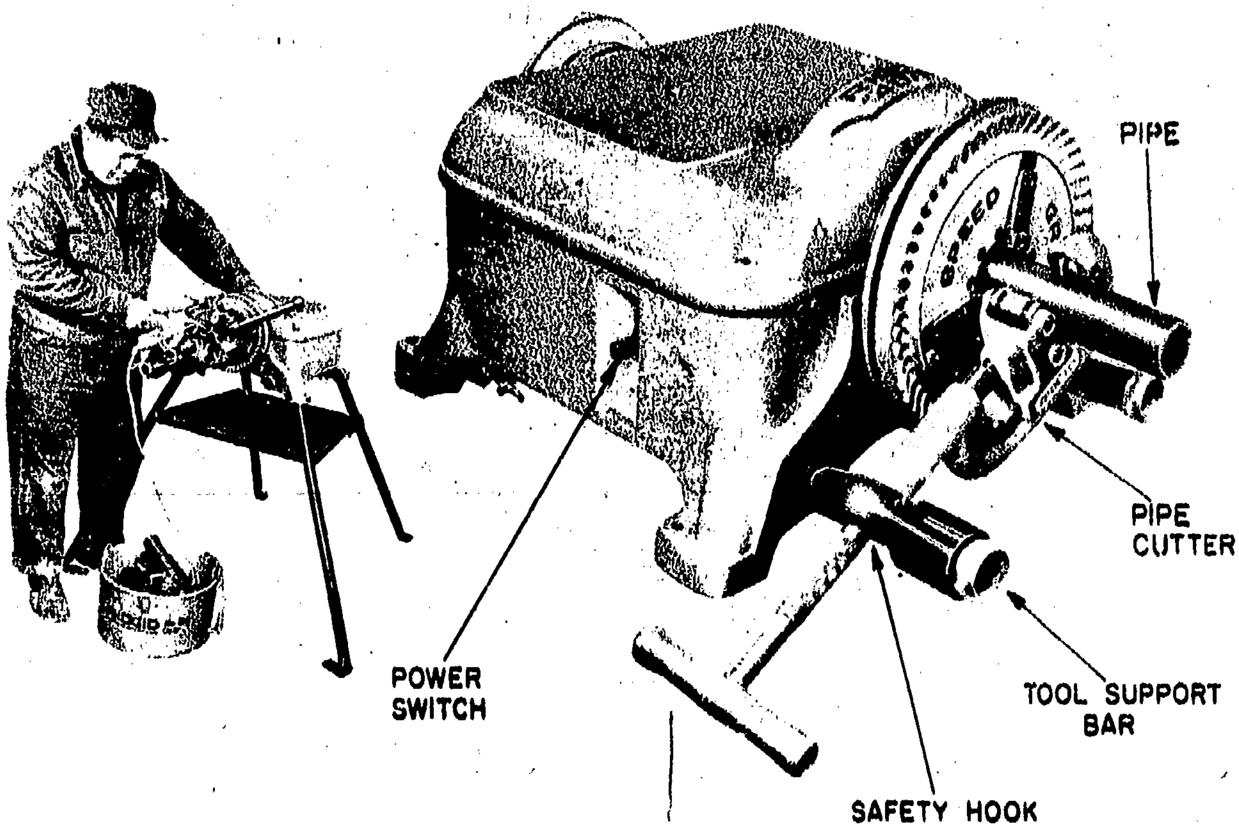
Methods commonly used in measuring threaded galvanized or black iron pipe are the same as for copper pipe and tubing. These methods were described earlier in the discussion on copper pipe and tubing and are illustrated in figure 4-23.

CUTTING, REAMING, AND THREADING.—Galvanized pipes can be cut, reamed and threaded by hand or with a power-operated machine. Information on the cutting, threading, and reaming of pipe by hand is presented in the Constructionman training manual. In this section we will explain how to cut, ream, and thread pipe with a power-operated machine. Power-operated machines are big time-savers, especially where a large volume of cutting is to be done. A typical power-operated machine is shown in figure 4-34.

In cutting galvanized pipe with the machine shown in figure 4-34, insert the pipe into the machine as shown. Then tighten the chuck jaws and rear centering jaws. Put the tool support bar in a position to support the cutter handle. Next, apply the cutter to the pipe as if you were cutting it by the manual method. Let the cutter handle rest on the tool support bar. Check to ensure that the cutter wheel is exactly on the mark where the pipe is to be cut. Then tighten the cutter blade so that it makes contact with the pipe. The next step is to turn the power switch to FORWARD position; then continue turning the cutter blade into the pipe until the cut is completed.

After the pipe has been cut, it can be reamed by using the machine shown in figure 4-34. To ream the pipe, first place the reamer in the pipe end. Let the handle of the reamer rest against the tool support bar. Turn on the motor, and then press the reamer into the pipe as needed to remove the burr.

The machine shown in figure 4-34 can also be used for threading pipe. To thread, first



54.391

Figure 4-34. — Electrically operated pipe machine.

insert the pipe into the front or rear end of the machine. Let it extend out of the speed chuck far enough that the threader will clear the chuck during threading. Next, center the pipe in the speed chuck and close the jaws with a snap-spin of the handwheel. If the pipe extends out the back of the machine, close the rear centering jaws. Then place the threader on the pipe in the usual way. Pull out the tool support bar to the desired position and allow the threader handle to rest on the tool support bar on the switch side. Hook the safety latch over the handle. Now turn on the switch and proceed to thread the pipe. During the threading operation, remember to use plenty of cutting oil.

JOINING. — THREADED PIPE JOINTS are commonly used on galvanized steel, galvanized wrought-iron and black iron pipe. This method of pipe joining involves connecting threaded male and female ends together.

To obtain a tight threaded joint, it is important that the threads be clean and in good condition. If the pipe has been exposed to the weather or banged around, see that the threads are checked very carefully. If necessary, run a die over the threads to straighten any that are damaged.

Cleaning both ends with a wire brush is a good start in making this joint after you have secured the pipe in a vise. Next apply a good thread lubricant on the male pipe threads. Use a Navy-approved nontoxic compound for water pipes, and mixed powdered graphite and oil for steam pipes. This "pipe dope" is not applied inside the pipe fitting, so as not to foul the system.

Start the joint by hand and turn it up as far as you feel it will go. Then slowly screw the remaining section of the pipe into the joint and tighten it with a pipe wrench. Do not use a hickey, or oversized wrench, or too much pull. Not all of the male threads need to be screwed into the joint. If all the threads are used, the wedging action of the tapered thread may cause the fittings to split.

How tight should you make a joint? Experience is the best teacher. Usually you will have two or three unused threads on a properly threaded pipe. If these steps are followed and the threads have been made properly, the joints will be tight for pressures several times the 150 psi working pressure of the class "A" fittings.

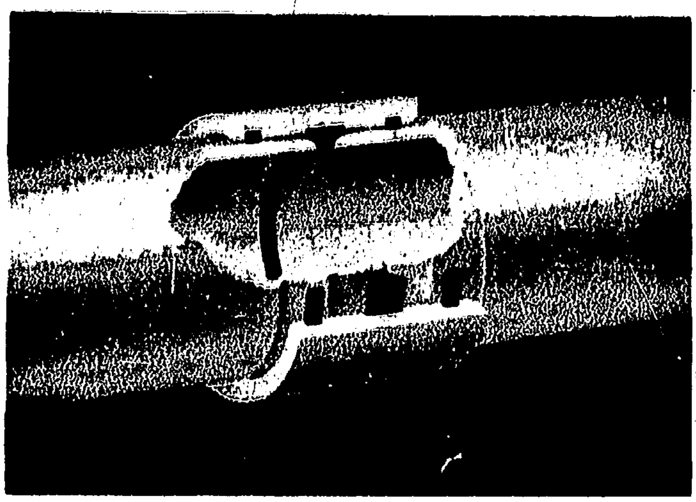
Cement-Asbestos Pipe

Cement-asbestos pipe is a composition of cement and asbestos. It is corrosion-resistant and will not rust or rot. It has a smooth interior surface which is a favorable friction factor. This pipe comes in sizes ranging from 3 to 36 inches in diameter for pressures of 50 to 200 psi and in lengths of 5, 10, and 13 feet. Being light in weight, cement-asbestos pipe is easy to handle. Cement-asbestos pipe is made with beveled ends, and adapters are available for connecting to pipe made of other materials.

Cement-asbestos pipe can be cut to any desired length or angle with a carpenter's saw or a transite pipe cutter. Or, it can be tapped for threaded service connections by using a water main self-tapping machine. With this machine the pipe may be tapped, threaded, and a corporation stop installed, while the pipe is under water pressure.

JOINTS AND FITTINGS.—Joints in CEMENT ASBESTOS pipe are commonly made with a specially designed COUPLING having three rubber SEALING RINGS. Three rings are fixed in grooves at the factory—ready for assembly.

Figure 4-35 shows a cut-away view of a completed joint with the three rings in proper position. As each pipe moves into position, during the process of assembly, the rubber rings in the two outer grooves of the coupling are compressed to seal the joint tightly. The T-shaped center ring forms a seal between the pipe ends. It eliminates jogs and pockets, and provides for uninterrupted flow. In this type of joint you have a tight and flexible connection.



54.50X
Figure 4-35.—Cutaway view of a cement-asbestos pipe joint.

54.51X
Figure 4-36.—Steps in assembling a cement-asbestos pipe joint.

A joint like that illustrated in figure 4-35 can be assembled entirely by hand. After checking to make sure the rings in the grooves of the coupling are in correct position, use the following two-step procedure, illustrated in figure 4-36, to make the connection.

1. Apply a thorough coating of lubricant to the male end of the pipe—all the way around (see view A, fig. 4-36). If a special lubricant supplied by the manufacturer is not available, a jelly-like soap solution can be prepared and used instead.

2. Pull or push the pipe together, as indicated in view B of figure 4-36, and the joint is complete.

In the absence of cement-asbestos fittings you can use double-bell cast-iron fittings and make them up as you would with cast-iron pipe, using sulfur compounds or lead.

Plastic Pipe

Plastic pipe may be flexible, semirigid, or rigid. It is furnished in sizes from 1/2 inch to 6 inches. Flexible pipe is furnished in coils up to 3,500 feet; rigid and semirigid in 20-foot lengths. Plastic pipe is designed to be used with liquids, gases, and air under pressure, and in plumbing systems to transmit corrosive acids. Plastic pipe may be installed below or above ground. There are several types of fittings on the market that can be used easily with plastic pipe. Principal advantages of plastic pipe over metal pipes are its flexibility, superior resistance to rupture through freezing, and complete resistance to corrosion.

MEASURING AND CUTTING.—Rigid and semirigid plastic pipes are measured in the same way as threaded steel pipe. Allowances

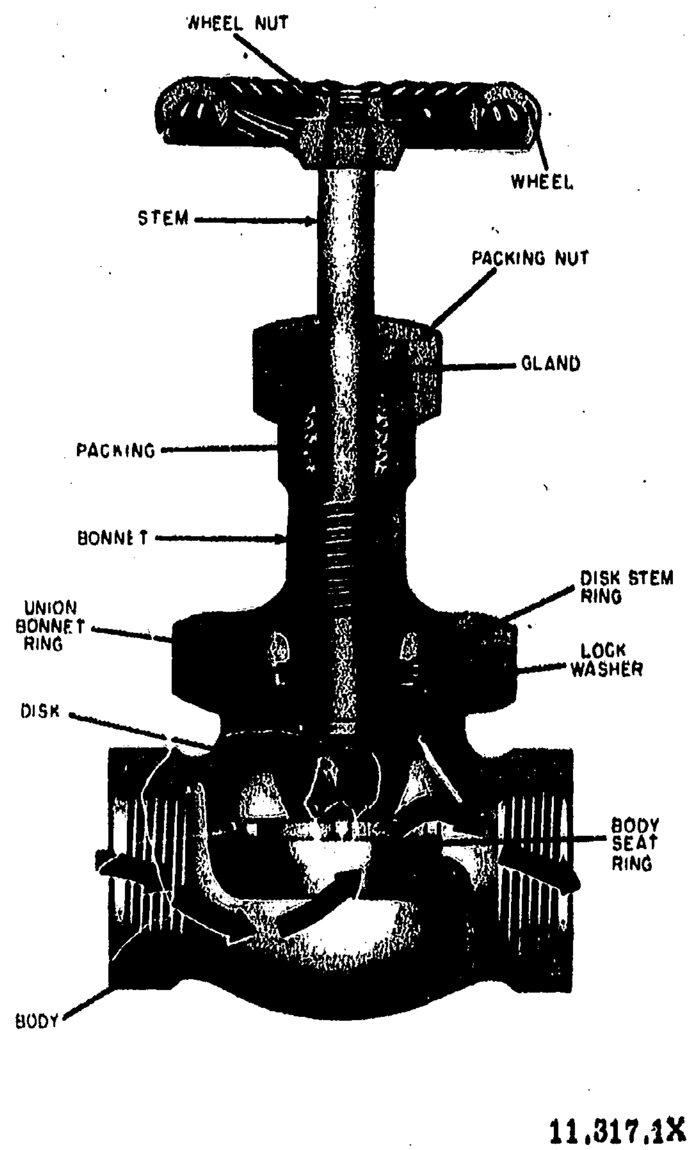


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Figure 4-37.—Globe valve.

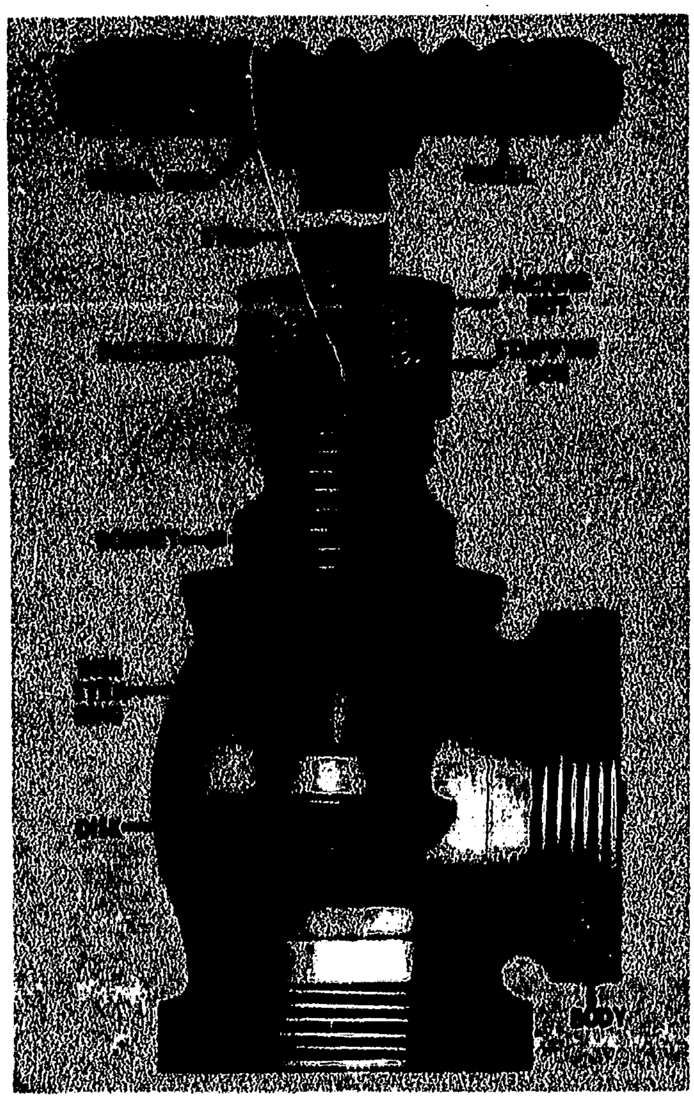

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Figure 4-38.—Angle valve.

must be made for the distance the pipe is inserted in the fitting. Accurate measurements are not required for flexible plastic pipe.

All types of plastic pipe are easily cut with a hacksaw. A fine-toothed blade (24 teeth per inch) is best.

JOINING. — Flexible plastic pipe joints are made by slipping the pipe over the fitting and fastening it with a stainless steel clamp. Fittings are made of nylon or stainless or galvanized steel and have annular rings for a tight fit.

Semirigid and rigid plastic pipe joints are either of the solvent welded or heat welded type. Solvent welds are made by applying a solvent to the outside of the end of the pipe and the inside of the fitting and then inserting the pipe into the fitting. Heat welds are made by use of a special electric heating tool which

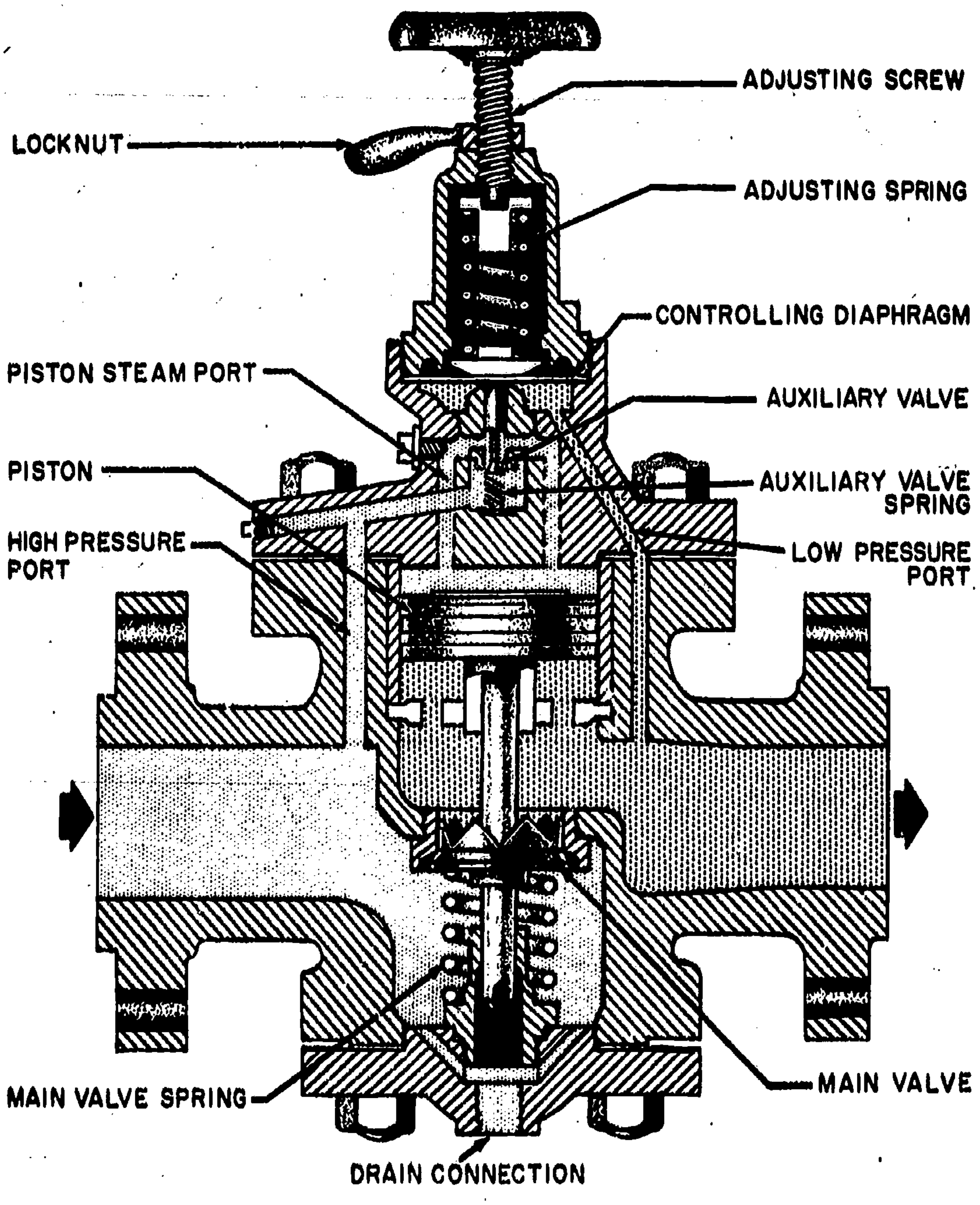

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Figure 4-39. — Spring-loaded pressure reducing valve.

comes in the same sizes as the pipe. The outside surface of the pipe and the inside surface of the fitting are heated until tacky (about 10 seconds). The pipe is inserted in the fitting and held in position a few seconds while the plastic cools and the joint is made.

VALVES

Flexibility in the operation of a water supply system requires the use of the proper valves for the condition to be controlled. Aside from completely stopping flow, valves are used for throttling or controlling quantities of water flowing in a pipeline. Other uses include pressure and level control, and proportioning flow. There is a wide variety of valve designs available, so we will not attempt to cover every type of valve that you may use in this discussion. However, we will take up a number of different types of valves which may concern the UT in his work.

The Globe Valve

The GLOBE valve, so-called because of its globular outline, is used for control of liquids, gases, and vapors by means of throttling. It is well-suited for services requiring regulated flow. (See fig. 4-37.) The closure disk and seats increase resistance to flow and permit close regulation of flow. The fluid flow is proportionate to the number of turns of the wheel in opening or closing the globe valve. The globe valve is ideal for service that requires frequent valve settings (throttling).

Globe valves can be fitted with fiber disks that are suitable for almost any type of service. If steam is used as the service, then metal disks, instead of fiber disks, should be used. The globe valve is designed to minimize erosion, in which case lower maintenance costs are likely where a wide range of flow is desired. But, operating costs may be greater since globe valves offer more resistance to flow than a gate valve and cut down line pressure.

An ANGLE valve is a globe valve in which the path of flow is changed 90° to the inlet. (See fig. 4-38.) The resistance to flow through an angle valve is less than if an elbow and a straight globe valve were used.

Pressure-Reducing Valves

Pressure-reducing valves are automatic valves which are used to reduce the supply pressure to a specified lower discharge pressure. The pressure-reducing valve can be set

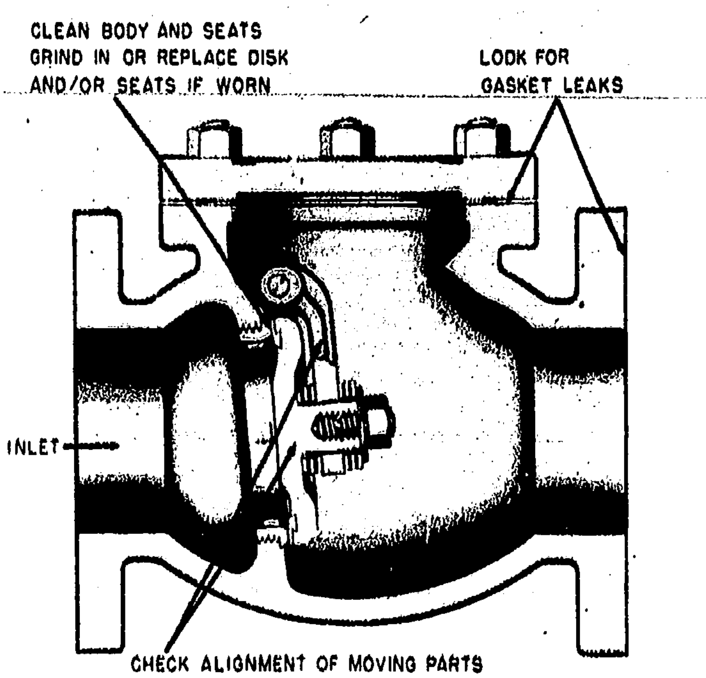

Figure 4-40. —Swing check valve.

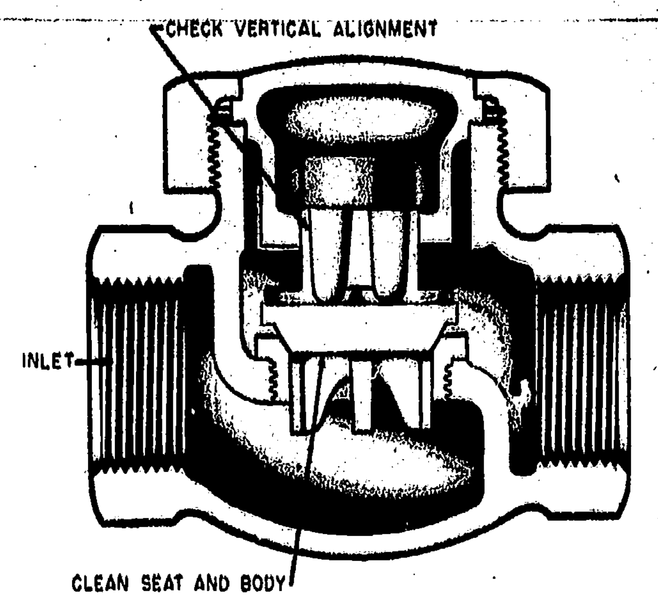

Figure 4-41. —Lift check valve.

for any desired discharge pressure, within the design limits of the valve. After the valve has been set, the reduced pressure will be maintained regardless of changes in the supply pressure (as long as the supply pressure is at least as high as the desired delivery pressure), and regardless of the amount of reduced pressure fluid that is used.

Various types of pressure-reducing valves are available. Figure 4-39 shows a spring-loaded type of pressure-reducing valve. In this valve, water enters on the inlet side and acts against the main valve disk, tending to close the main valve. However, water pressure is also led through ports to the auxiliary valve, which controls the admission of water pressure to the top of the main valve piston. This piston has a larger surface than the main disk; therefore, a relatively small amount of pressure acting on the top of the main valve piston will tend to open the main valve, and also allow water at reduced pressure to flow out the discharge side.

Pressure-Relief Valves

PRESSURE-RELIEF valves discharge water from pipes or systems when a maximum desired pressure is exceeded. They are installed on low-pressure systems fed through pressure-reducing valves from high-pressure supplies, to ensure against damage if the pressure-reducing valves fail to operate. They are also used on pump headers discharging into large supply mains, to relieve the high surge pressure which builds up between the time a pump is started and the time required for water in

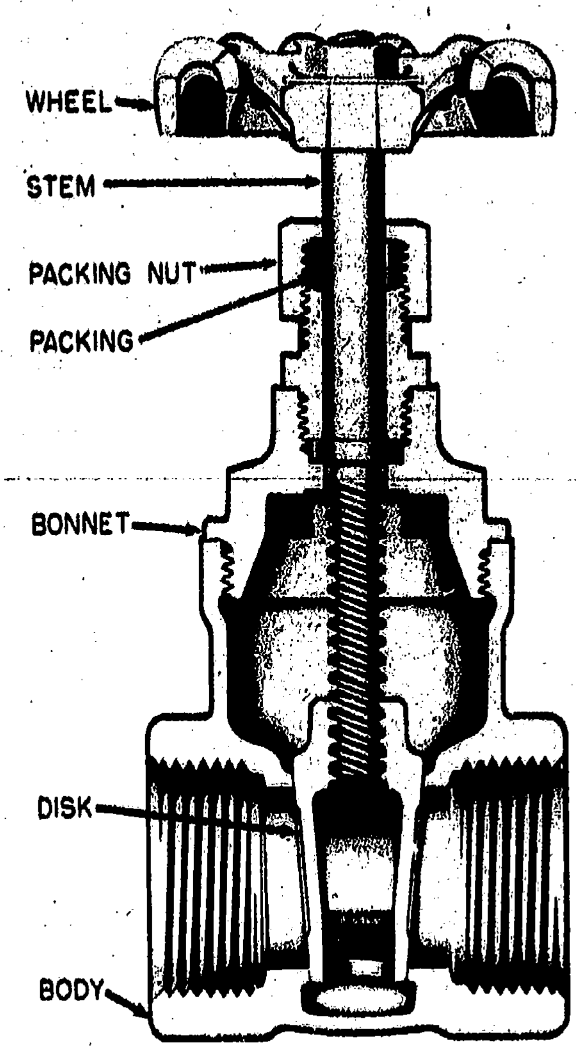

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Figure 4-42.—Gate valve.

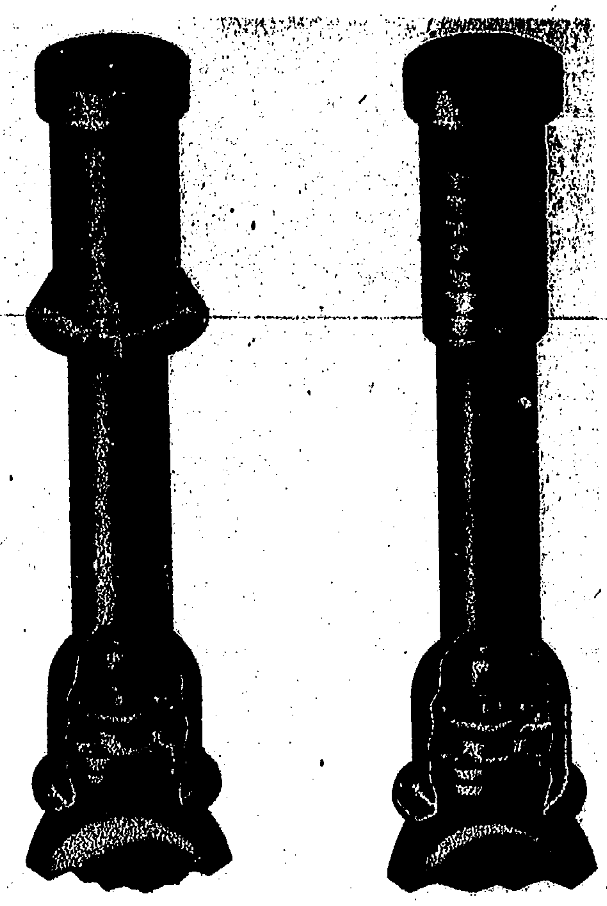

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Figure 4-43.—Valve boxes.

the main to reach full velocity. Relief valves are essentially pressure-reducing valves in which the control mechanism responds to pressure on the inlet, rather than the outlet, end.

Check Valves

The principal use of the check valve is to prevent backflow in pipelines. The valves are entirely automatic in action, and are used where flow of liquids, vapors or gases in one direction only is required. Check valves fall into two general groups: swing check valves and lift check valves. A SWING CHECK valve is usually used where full flow is desired, and should be installed so that the disk is held to the seat and will close by gravity. (See fig. 4-40.) A LIFT CHECK valve is usually used for air or gases, or when operation of the check valve is very frequent. (See fig. 4-41.) Lift check valves will seat more positively and tightly than swing check valves. The disk is seated by backflow, or by gravity when there is no flow.

The Gate Valve

The GATE valve allows fluid to flow through in a straight line. (See fig. 4-42.) There is little resistance to flow, and less friction and pressure drop, provided the valve disk is kept fully opened or fully closed. A gate-like disk, moved by a stem screw attached to a handwheel, moves up and down at right angles to the path of flow. The gate valve releases a variable amount with each turn. The second turn may release three times as much as the first, and the third, five times as much. When closed, the gate seats against two seat faces to stop flow. Gate valves must always be operated in either their fully open or closed position, and should not be used for throttling. A partly closed gate will cause vibration and chattering, and result in damage to the seating surfaces.

When gate valves are opened and closed only at infrequent times, they last a long time and require little maintenance. If a gate valve is operated over 10 times a day, every day, it will quickly wear out, and a globe valve should be substituted. The wear will be found on the down-stream faces of the seat and disk, because the line pressure forces all the wear on these surfaces. Since the upstream faces are seldom damaged in this way, longer life of the valve will result if worn gate valves are reversed.

Four types of disks are used in gate valves; they are the solid-wedge, flexible-wedge, split-wedge, and double disk. The most popular is the solid-wedge disk, which is a single moving part that will not jam because of misalignment of mating parts, whether the stem is up, sidewise, or down. Ideal for steam service and well-suited for water and for many other fluids, it is also the best type for turbulent flow because it will not vibrate or chatter.

Split-wedge and double-disk valves have wedges that come in several parts. As the valve is tightened after closure, the wedge or spreader forces the disk outward and hard against the body seat. The first opening turn releases the disks, and continued turns raise them clear of the seat openings. Such parallel seats can be repaired or replaced easier than those accommodating a tapered-wedge disk. Double disks cannot always be used. To assure proper closure, it is advisable not to install a double-disk valve with its stem below horizontal, since it is apt to vibrate in steam service, and to cause the disk and seats to wear at a high rate. However, the valve is good in pipelines conveying liquids or noncondensing gases at normal temperatures.

Valve Operation

When valves are operated manually, there are several sound rules to follow. In manually opening a valve, it should be opened all the way, then closed down one-quarter turn of the handwheel. This will prevent the valve from sticking in the open position. Valves should be opened slowly and at an even rate to reduce the hazard of water hammer. Unless otherwise indicated, valves are opened by turning the handwheel counterclockwise. Always consult the manufacturer's instructions for the operation of a specific type of valve.

Many valves in a water supply system are power-operated and require little operating attention, except in the case of power failure. When it then becomes necessary to close or open such a valve by manual operation, consult the manufacturer's instructions for such emergency measures. Most power-operated valves are equipped with safety devices to allow for such operation.

Appurtenances

Appurtenances which aid in the control of valves include valve boxes, floor stands, and post indicators. Each of these appurtenances is discussed briefly below.

VALVE BOXES.—Street valves must be accessible for turning off and on; and, with large valves it is desirable that the entire valve be accessible for servicing. For the first purpose, valve boxes are used (see fig. 4-43), and for the second, vaults or manholes are used. Since valves are placed at various depths, valve boxes are made in two or more pieces which telescope so as to give adjustable lengths.

FLOOR STANDS.—Valve controls may be mounted on floor stands for operating valves below a floor. They are operated manually by turning the handwheel, or by automatic controls. Some floor stands are equipped with indicators which show when valves are opened or closed. Floor stands (see fig. 4-44) are essentially an extension of the valve stem.

POST INDICATORS.—Post indicators (see fig. 4-45) provide a convenient method of operating nonrising-stem gate valves placed below the ground or floor levels. They are used principally in fire-flow systems, and in this function must be fully approved by the Underwriters' Laboratories and the Associated Factory Manual Fire Insurance Companies (indicated on the post by the letters UA and FM). The indicator post is operated by an attached vice when not in use. The valve is opened by turning the wrench to the left, unless otherwise indicated. The open or closed position of the valve is clearly indicated by the target plates which show the words "Open" and "Shut" in glass protected openings on both sides of the post. Most post indicators are sealed open for safety's sake. If the seal has been broken, the operator should report the tampering to higher authority immediately.

Installation of Valves

As a UT, you will have to install various types of valves. Some general instructions that usually will apply when installing valves in water supply systems are given below.

Valves should be handled carefully. If a valve is dropped, a part vital to dependable operation may break or become deformed.

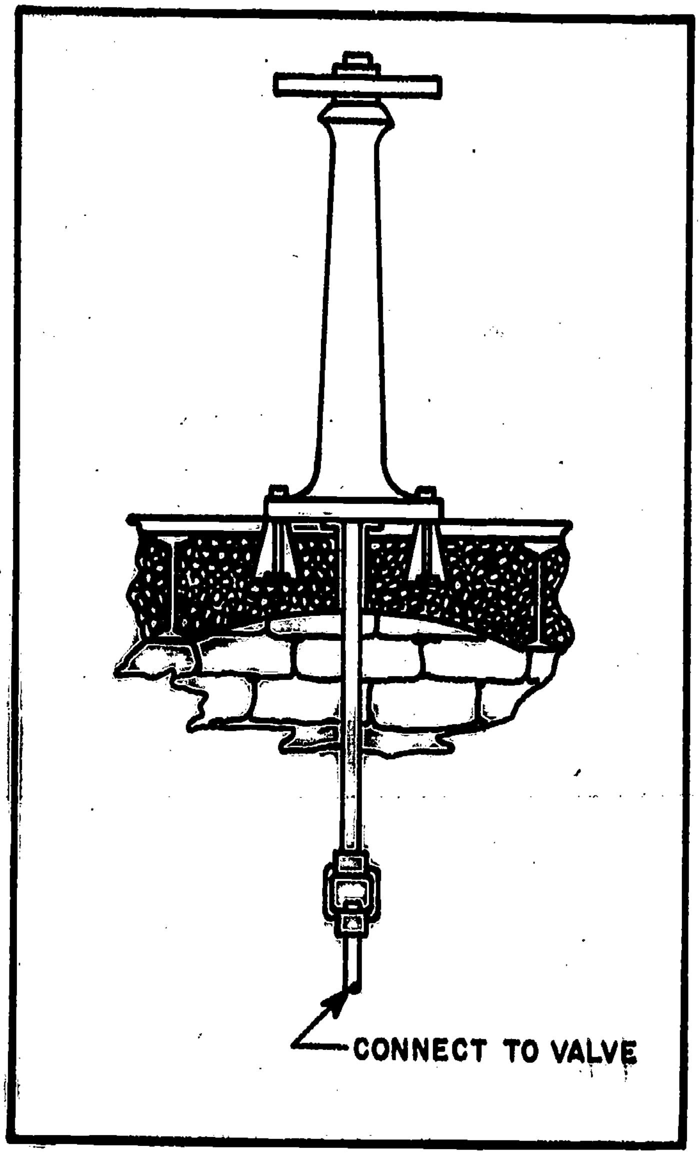

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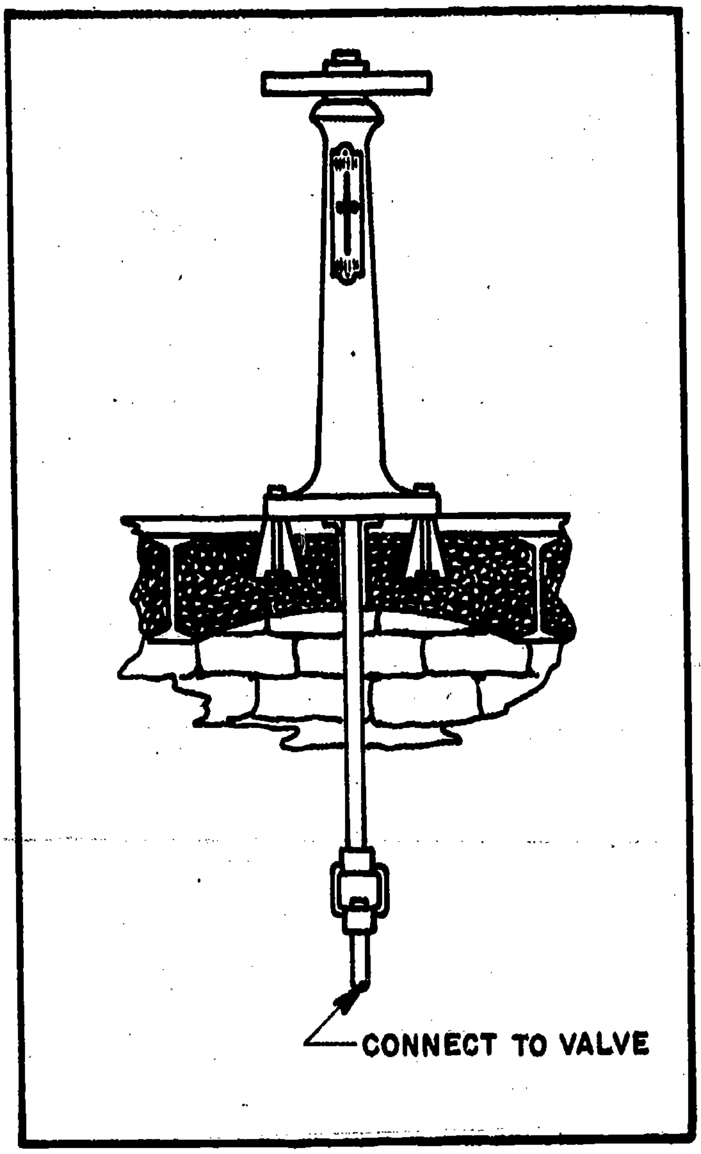
Figure 4-44.—Floor stand.

Valves should not be located where they are exposed to damage from blows. They should be accessible, and it should be possible to open them fully. Valves should not be installed where they must carry the weight, sag, or expansion of a line.

It is important that valves be in the closed position during installation. In closed position, operating parts are less likely to become twisted and areas of closure are protected.

Overlength threading should be avoided on the joining pipe, so that the end of the pipe will not project into the valve and injure the valve seat.



54.203X
Figure 4-45. — Floor stand with post indicator.

Sealing compound should be applied only to the pipe threads, and care taken that it does not get into the valve to injure the seat.

The pipe should be cleaned before a valve is installed, and blown out again with compressed air (if necessary) after installation.

In attaching a valve, the wrench should be used on the hex nut nearest the pipe to which the valve is being connected.

The packing in a new valve should be tightened after it has been in use for a short time, but it should not be allowed to become tightly compressed.

Bear in mind that the above are general instructions and may not apply to the installation of all types of valves. For specific instructions, follow the recommendations of the manufacturer of the valve being installed.

FAUCETS

As a Utilitiesman you may often be called upon to install or make repairs to faucets. There are many types of faucets in general use, among which are the plain bibb, hose bibb, combination, and lavatory type faucets.

The plain bibb faucet (see fig. 4-46) is usually made of brass, but on occasion may be chromium-plated. This faucet is frequently installed on laundry tubs.

The hose bibb faucet, as indicated in figure 4-46, is similar in appearance to the plain bibb except that the outlet has threads so that a garden hose may be screwed onto it. The hose bibb faucet is used where outside hose connections to faucets are needed.

You will probably recognize the combination faucet which also is shown in figure 4-46. This type of faucet generally is used to combine the flow from hot and cold water pipes. A main feature of this faucet is that it enables the water to be tempered as it is discharged through a single spout. Its most common use is on laundry tubs and kitchen sinks.

The lavatory faucet (see fig. 4-46) is usually chromium-plated. It is used as the shutoff for the hot and cold water connections on an ordinary lavatory. The lavatory faucet may be of the self-closing or combination types.

WATER METERS

Water meters are used to measure the flow of water, within a line, to a given point of distribution—such as laundries, housing areas, and so on. There are various types of water meters. One type that you will be concerned with is the disk type of volume meter, which is used chiefly for services supplied through pipes less than 1 1/2 inches in diameter, although they are made in sizes up to 6 inches.

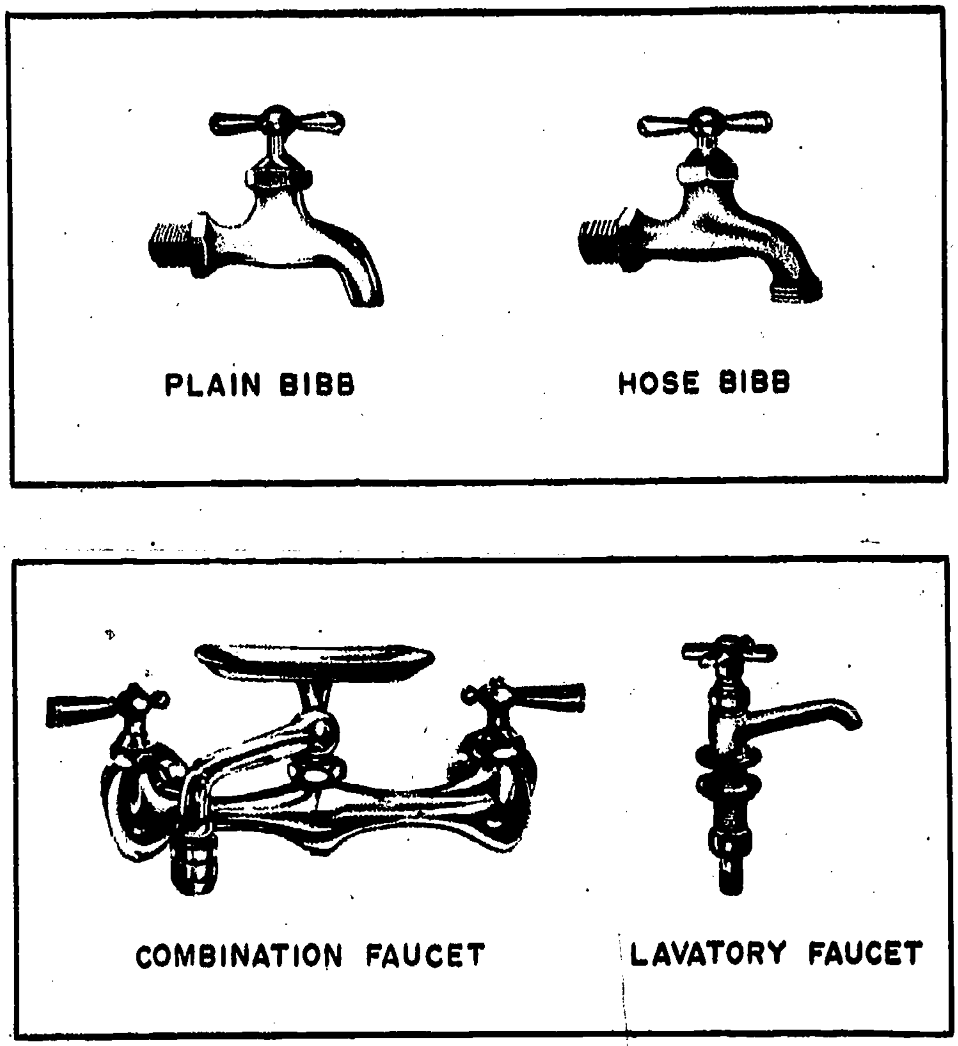


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Figure 4-46. — Types of faucets.

Figure 4-47 illustrates the nutating-disk type of volume meter. This type is mainly used for individual service connections as it is accurate for very low flows. Flows above normal cause rapid wear. The disk type of meter contains a measuring chamber of definite content in which a disk is actuated by the passage of water. Each cycle of motion of the disk marks the discharge of the contents of the measuring chamber. By means of gearing, the motion of the disk is translated into units of water volume on the register dial.

When installing a water meter, make sure it is horizontal and that it operates under back pressure. The meter will probably be located near the pressure-reducing valve below ground level, so in below-freezing temperatures see that it is protected from exposure.

Water is measured in terms of rate-of-flow (volume passing in a unit time), or total volume. Units and equivalent usually are as follows:

Unit	Equivalent
Cubic feet per second (c.f.s.) . . .	448.83 gallons per minute (g.p.m.)
c.f.s..	646,315 gallons per day (g.p.d.)
g.p.m.	0.00223 c.f.s.
g.p.m.	1440 g.p.d.
Million gallons per day (m.g.d.).	1.547 c.f.s.
m.g.d.	694.4 g.p.m.
cu. ft.	7.48 gal.

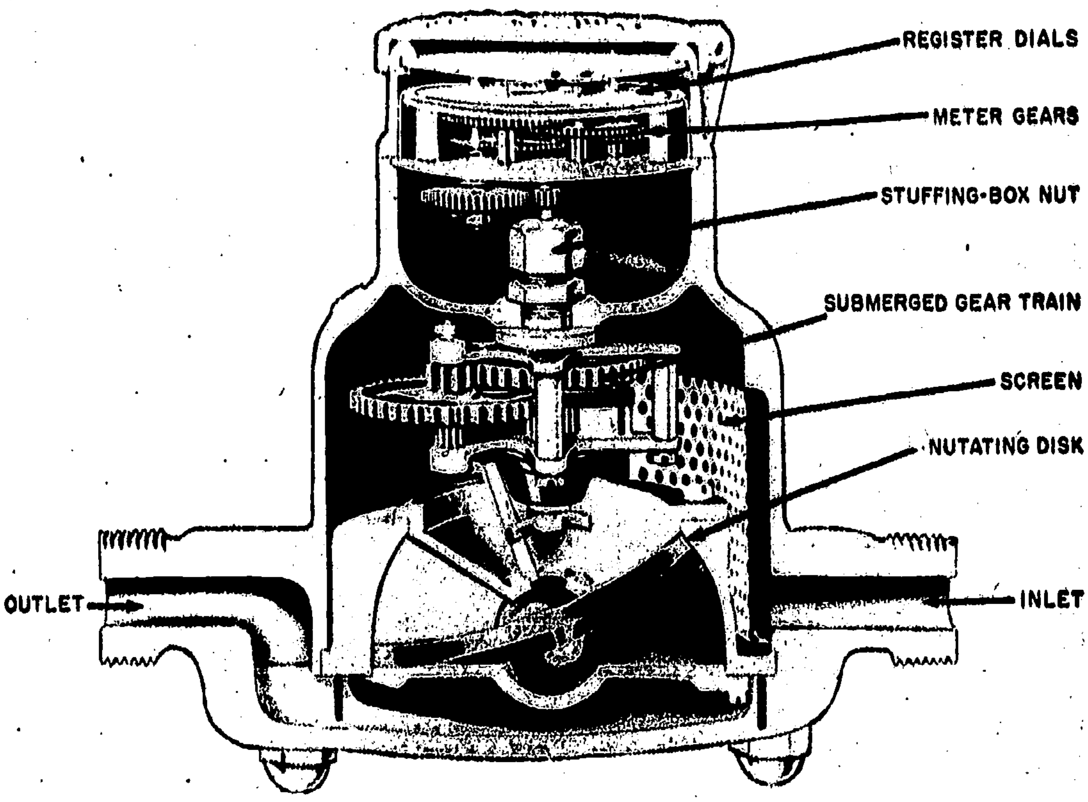

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Figure 4-47. — Nutating-disk meter.

A point to remember is that: IN READING A METER, YOU SHOULD FIRST DETERMINE WHETHER IT IS MEASURING THE WATER FLOW IN CUBIC FEET OR IN GALLONS.

Meter Dials

There are two general types of meter dials: the straight-reading type and the circular-reading type.

The STRAIGHT-READING DIAL, illustrated in figure 4-48, may be read in the same way as mileage on an automobile. When the meter register has one or more fixed zeros, always be sure to read these fixed zeros in addition to the other numerals.

In the CIRCULAR-READING DIAL, when a hand on any scale is between two numbers, the lower number is read. If the hand seems exactly on any figure, check the hand on the next lower scale. If that is on the "1" side of zero, read the figure on which the hand lies; otherwise, read the next lower figure. The procedure for reading the circular-reading dial, shown in gallons in figure 4-49, is to begin with the "1,000,000" circle and read

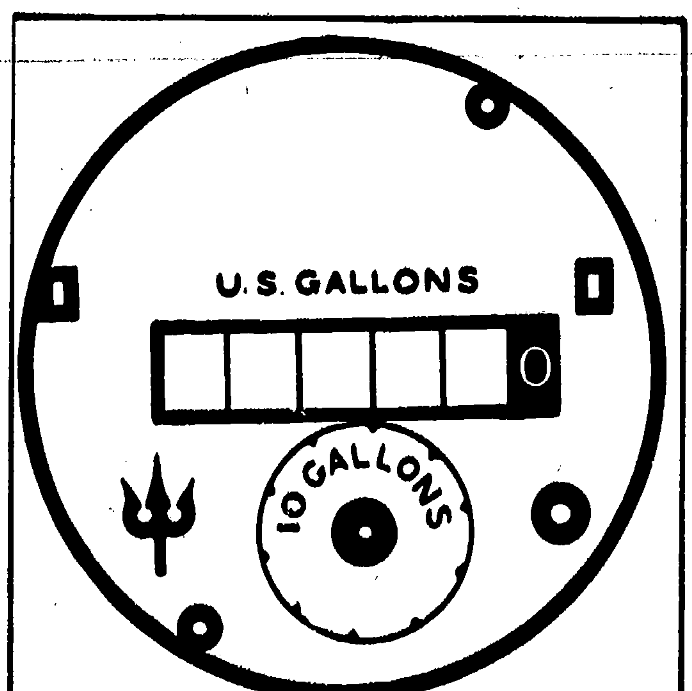

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Figure 4-48. — Straight-reading meter dial.

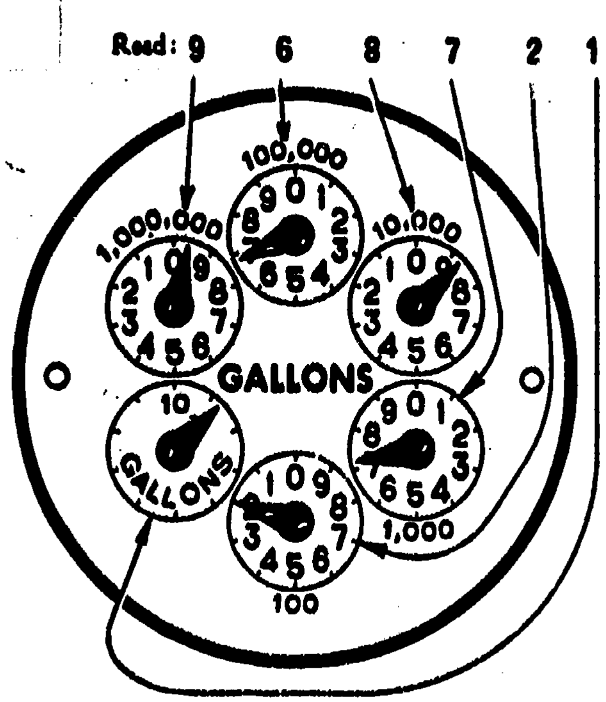
clockwise to the "10" circle, the scales registering 9,6,8,7,2, and 1, respectively, making a total of 968,721 gallons.

Obtaining Current Reading

As the registers are never reset while the meters are in service, the amounts recorded for any given period must be determined by subtraction. To obtain a current reading, simply subtract the dial reading from the last recorded reading. It must be remembered that the maximum amount that can be indicated on the usual line meter before it turns to all zeros and starts all over again, is 99,999 cubic feet, or 999,999 gallons. Thus, to obtain a current measurement when the reading is lower than the last previous one, add 100,000 to the present reading on a cubic feet meter, or 1,000,000 to the present reading on a gallon meter. The small denomination scale, giving fractions of one cubic foot or ten gallons, is disregarded in the regular reading. It is used for testing purposes only.

FIRE HYDRANTS

The fire department (or safety office) is responsible for the selection and use of firefighting



61.13(54)X

Figure 4-49.—Reading the circular-reading meter dial in gallons.

equipment, including fire hydrants. It is a responsibility of the UT, though, to ensure that water is available to the hydrant and that control valves operate properly.

Most fire hydrants consist of a cast iron barrel with a bell or flange fitting at the bottom to connect to a branch from the main; a valve of the gate or compression type, with a long stem terminating in a nut above the barrel; and one or more outlets. There are many designs of fire hydrants, two of which are the dry-barrel hydrant and the wet-barrel hydrant.

In cold climates, where freezing occurs, DRY-BARREL HYDRANTS are used. (See fig. 4-50.) With this type, the drain valve must be kept open in all systems where the ground water level is below the hydrant foot in order that the barrel will drain and will not freeze in cold weather. You will find that a box placed over a hydrant affords some protection against freezing and leaves the top of the hydrant free of snow and ice. The hydrant is equipped with two 2 1/2-inch hose outlets, and a 4 1/2-inch pumper outlet whose threads conform exactly to National Standard Fire Hose Threads.

Where freezing temperatures do not occur, WET-BARREL (or CALIFORNIA) HYDRANTS may be used. (See fig. 4-51.) With this type, all packing glands should be kept in condition to prevent leakage as well as to allow free operation of the stem controlling each outlet. Valve seats for wet-barrel hydrants afford easy access for inspection.

Hydrants exposed to traffic hazards must be protected by appropriate guards. Most damage is caused by accidents or improper or careless operation. Much of it can be prevented if operating personnel are made to realize that a properly functioning fire hydrant is important to the protection of life and property at the activity. Without much extra labor or effort, they can take many precautions to keep the hydrant structure in good condition. Several general precautions are listed below.

1. The operation of fire hydrants should be restricted to responsible personnel ONLY, trained in this and allied work, such as firefighters or utility maintenance and operating personnel.

2. For opening and closing the hydrant, use ONLY an approved hydrant wrench. The reason

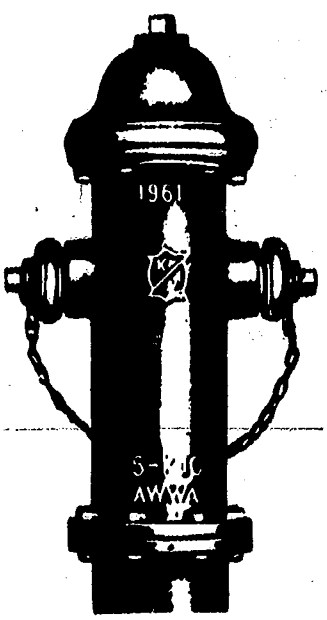
Standard Model

Compression Type

Test Pressure:
Water 300 lbs.

Working Pressure:
Water 150 lbs.

Sizes:
Main Valve 4¼", 4½", 5¼"
Standpipe ID 7"



Exterior view showing marking cast on standpipe. Direction to open cast on cap.

PART	MATERIAL
CAP BOLT NUTS	BRONZE
OPERATING STEM NUT	BRONZE
ALEMITE FITTING	STEEL
"O" RING WEATHER SEAL	BUNA N SYNTHETIC RUBBER
CAP	CAST IRON
ALLEN HEAD SETSCREW	STEEL
LOCK NUT	BRONZE
COVER PLATE	CAST IRON
COVER PLATE BOLTS AND NUTS	RUST-PROOFED STEEL
"O" RING PRESSURE SEAL	BUNA N SYNTHETIC RUBBER
COVER PLATE GASKET	CORK FIBRE
NOZZLE CAP HOOK	STEEL
NOZZLE CAP GASKET	RUBBER
NOZZLE	BRONZE
NOZZLE CAP	CAST IRON
NOZZLE SCREW	BRONZE
NOZZLE CAP CHAIN	STEEL
UPPER STANDPIPE SECTION	CAST IRON
STANDPIPE BOLTS AND NUTS	RUST-PROOFED STEEL
STANDPIPE GASKET	SPECIAL COMPOSITION
STEM	C.R. STEEL
SEAT REMOVING WRENCH GUIDE	BRONZE
WRENCH GUIDE SETSCREW	BRONZE
LOWER STANDPIPE SECTION	CAST IRON
DRAIN VALVE FACING	TREATED LEATHER
DRAIN VALVE	BRONZE
ELBOW BOLTS AND NUTS	RUST-PROOFED STEEL
ELBOW GASKET	CORK FIBRE
SEAT RING	BRONZE
SEAT RING GASKET	ASBESTOS FILLED COPPER
DRAIN VALVE KEY	STEEL
TOP PLATE	CAST IRON
MAIN VALVE	BALATA
FULL COVER BOTTOM PLATE	CAST IRON
ELBOW	CAST IRON
DRAIN TUBING	BRONZE

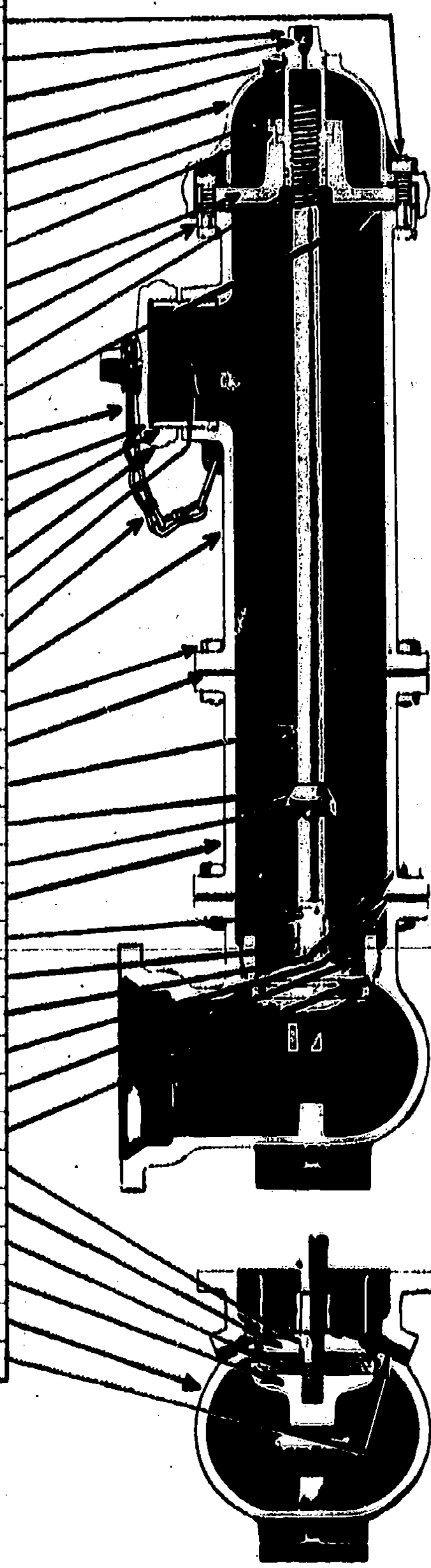


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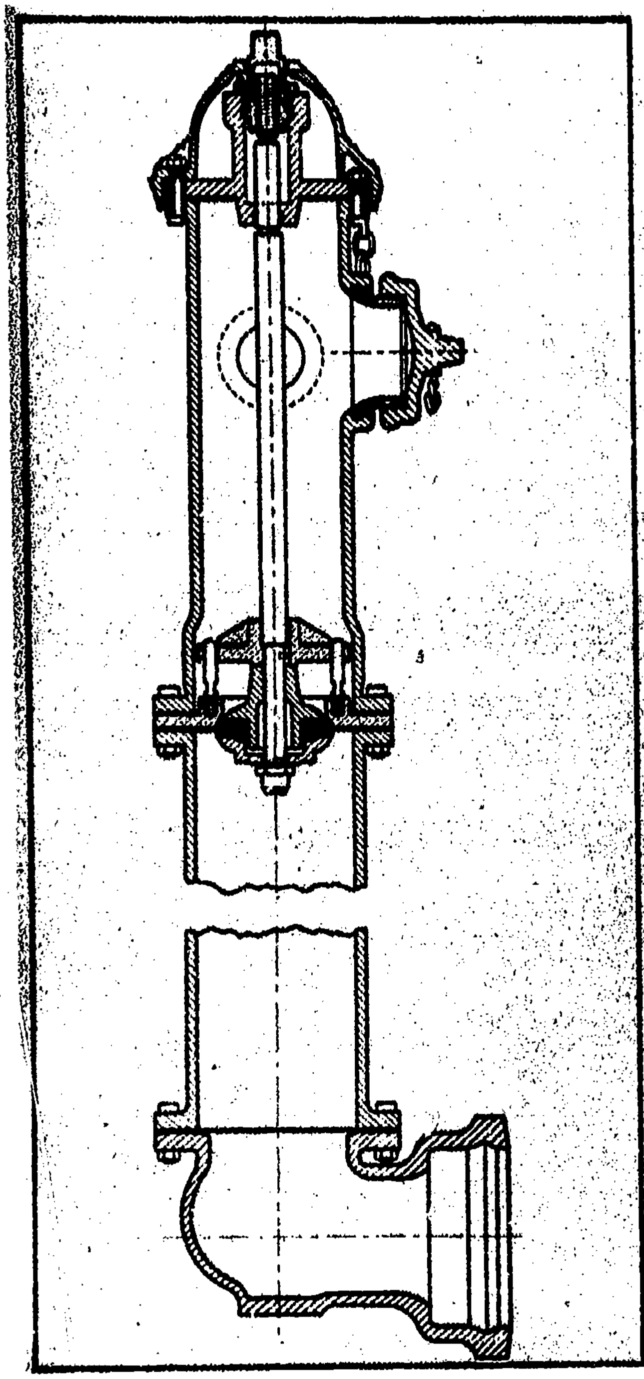
Figure 4-50. — Dry-barrel fire hydrant.



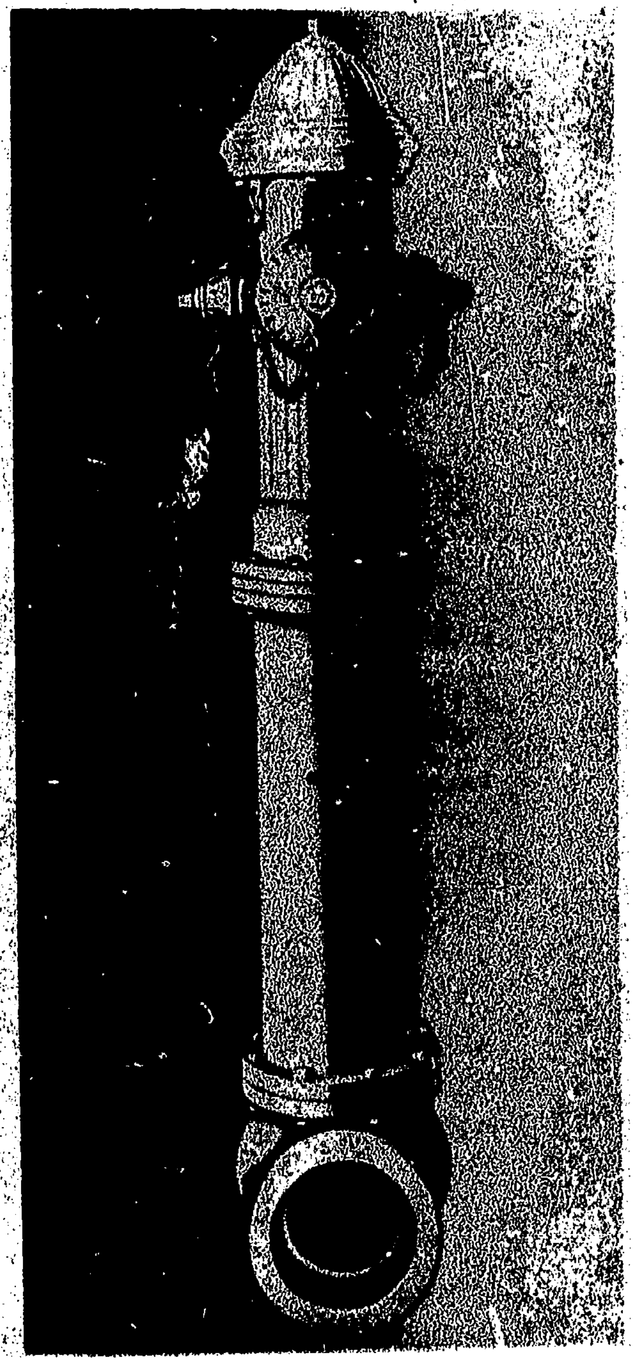


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Figure 4-51.—Wet-barrel type, or California, fire hydrant.

is that ordinary wrenches will ruin the operating nut.

3. Keep the hydrant drained when it is not in use. This is particularly important in cold climates when ice in the hydrant may make it inoperative.

4. Pipes should be connected only to draw off water for firefighting, except in emergency. Any such connection must be removed immediately after an emergency. Connections made to provide a temporary supply for vehicle washing, irrigation, and so on should not be permitted.

5. The hydrant valve should be kept in either the wide open or fully closed position and never used to throttle the flow of water. If it is necessary to restrict the flow, separate globe

valves may be attached to the hydrant discharge outlet.

LAYING WATER PIPES

An important phase in the installation of a water system is laying the belowground water service pipes. Information that will aid you in laying these pipes is given below.

Regardless of the pipe material used, sharp bends and dead ends should be anchored by rodding or concrete anchors. Where the pipe is setting in saddles, metal straps may be used. Even though the pipe is installed within a ditch these will help support and hold the pipe in place.

Pipe should be founded on solid trench bottoms. Automatic air-release and vacuum valves should be installed at prominent peaks on long supply mains to permit escape of air, while the pipe is being filled, and entrance of air when it is drained. Elsewhere in the distribution system air normally can be released and taken in through service lines.

Flow in water pipes may be achieved by gravity with the use of an elevated tank, or by use of a pumping system. Where pipe must be placed in a sloping trench, the slope should be as even as possible to keep the pipe from bending and breaking. After the trench is dug, it is a good idea to lay your pipe and fittings alongside it. Before you start placing the pipe, shut off the water in the main supply line. The placing should start at the main supply tee.

TESTS AND TESTING PROCEDURES

Of course, newly installed pipe has to be tested for leaks. This can be done by means of air or water.

To make an AIR TEST, plug up all openings in the system, connect a source of compressed air to the system, and bring the pressure up slowly to the designed working pressure. Use a soapy water solution and cover each joint and check for leaks. If leaks are present, the location of each can be detected by bubbles formed by the escaping air. When a leak is discovered, mark each spot with chalk or soapstone. DO NOT, AT THIS TIME, ATTEMPT TO REPAIR THE LEAK. After the line has been tested completely, relieve the pressure from within and make the repairs to the joint. Repeat the testing and repairing procedures until all leaks have been located and repaired.

The procedure for making a WATER TEST is similar to that used for an air test. Water is used instead of air, and you do not use a soapy water solution to cover the joints. The pipe is filled with potable water, and pressure is applied and maintained by means of a hand pump. Care should be taken that no air has been retained in the pipe being tested. Let it stand under operating pressure from 4 to 8 hours, making your inspections for leaks during this period.

BACKFILLING

When ready to backfill the ditch, tamp the soil around the pipe. This can be done in two ways with water pipe: by hand-tamping or by use of water.

You must exercise care in backfilling to keep the pipe straight and minimize settlement. Soil used to backfill around the pipe should be as free as possible from rocks and debris. Do not throw fill material directly on the exposed pipe, as this is likely to damage the pipe or move it out of alignment. The correct way is to DROP THE FILL MATERIAL ON EITHER SIDE OF THE PIPE.

When you have water available, it can be used instead of the tamper; this is especially true when you have a short run to backfill. Fill the ditch completely with loose soil. Attach a piece of pipe to a water hose and push it through the loosely replaced soil until it touches the water main. Turn on the water and let it run until it appears on the surface. This method will allow all the earth to be replaced except the volume equal to that of the pipe.

DISINFECTION OF WATER SUPPLY SYSTEM COMPONENTS

Water mains, wells, filters, storage tanks and other components of a water supply system become contaminated during installation and repair. Flushing the system to remove dirt, waste, and surface water is the first step in disinfecting the water system, but it is not a sufficient safeguard. To ensure a safe water supply, each unit of the system must be thoroughly disinfected before it is placed in operation. The chemicals used in disinfecting a water supply system are the same as those used in disinfecting water; e.g., a hypochlorite solution or chlorine gas.

Dosage Required

The chlorine dosage required to disinfect any unit thoroughly depends upon the contact time, and the amount of jute, untarred hemp and organic chlorine-consuming material present. Under average conditions, the following minimum dosages are recommended:

Unit	Minimum dosage (p.p.m.)
Pipe	50
Storage tank	50
Filter	100
Well	150

The volume of water in the unit to be disinfected must be computed before the chlorine dosage can be estimated. The volumes of water contained in different sizes of pipe are listed below.

Pipe diameter (in.)	Volume per ft. of pipe (gal.)
6	1.47
8	2.61
10	4.08
12	5.88
16	10.45
20	16.32

Applying Disinfectant

The following methods of applying disinfectants should be observed:

1. Liquid chlorine is applied by portable gas chlorinators. Chlorine cylinders should not be connected directly to mains because water may enter the cylinder causing severe corrosion and resulting in hazardous leakage.

2. Hypochlorite solution is usually applied by measuring pumps, gravity-feed mechanism or portable pipe disinfecting units.

In applying disinfectants, follow the procedures given below.

Before adding disinfectant, the section should be flushed thoroughly with water until all dirt and mud are removed. A velocity of at least 3 feet per second is required for adequate scouring.

Stop all branches and other openings with plugs or heads properly braced to prevent blowouts.

Disinfect the water mains in sections introducing the disinfecting agent through taps or hydrants at the ends of each section. If a portable gas chlorinator or hypochlorinator is available, introduce the discharge from the chlorinator into an auxiliary water line leading to one of the hydrants or taps. Bleed the air from the line at high points and crowns. Add the predetermined chlorine dosage as the main is slowly filled with water. Continue feeding until the water discharging at the other end of the section contains the desired residual chlorine. Let the chlorinated water remain in the contaminated unit or section for 24 to 48 hours. Then flush until the chlorine residual is only that amount normally in the supply. Make daily bacteriological analyses of water samples until the analyses show no further disinfection is required.

In case a chlorinator is not available, feed a strong hypochlorite solution into the main from a pail through the highest hydrant top or valve with the bonnet removed. Add the hypochlorite and water until the main is full and the chlorine residual is about 50 p.p.m. Test the residual at the far end of the main. Bleed out any air trapped in the line.

If the mains are to be disinfected under pressure using supply or booster pumps, feed the chlorine into the main with chlorinators or hypochlorite feeders. Take care to ensure adequate and accurate distribution of the disinfecting agent when using pumps.

The use of dry calcium hypochlorite directly in mains is not uniformly effective because of unequal mixing with the water. Therefore, if calcium hypochlorite is to be used, a solution of this chemical should first be prepared.

Emergencies

Natural contamination of water supplies may increase markedly because of emergency conditions. Standby or portable chlorinators must be maintained in working condition to meet emergency disinfection requirements in water supply components. This equipment cannot, however, be expected to make drinking water safe after bombing, sabotage, or biological warfare have rendered it unsusceptible to disinfection by chlorination.

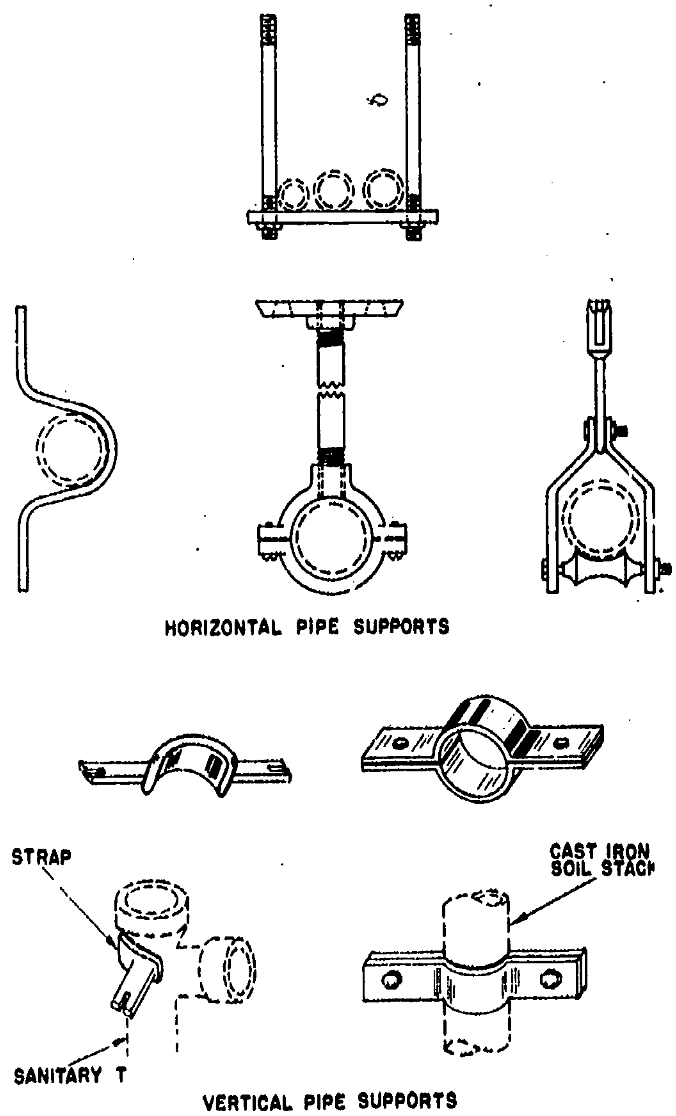

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Figure 4-52.—Methods of supporting cast-iron soil pipe and galvanized pipe.

PIPE SUPPORTS

Where pipes are exposed aboveground and in the interior of buildings supplying air, water, or steam, they must be provided with adequate support to prevent sagging. Adequate support or suspension is necessary because the weight of the pipes, plus the fluid in them, can cause breaks, strain joints, and distort and cause leaks in valves.

The main supply pipe (vertical or horizontal) must be adequately supported to take its weight off the fitting and to prevent future leaks. There are many ways such supports may be effected; refer to figure 4-52, showing some of the methods used to support cast-iron soil pipe and galvanized pipe.

Fixture supply risers are pipes taken off of the supply pipes to furnish air, water or steam to the fixtures that will be installed. These risers may be in the wall or exposed. They must be made up tight and tested prior to being closed up in a wall. All vertical fixture risers should be supported at each floor level or in a change of direction. They should never depend upon the horizontal fixture supply branches for support.

INSULATION

To protect the piping system and personnel when piping is exposed, insulation is installed around the pipes. Insulation is used to prevent loss of heat in hot-water pipes, or to keep heat out of cold-water pipes. It also is used to protect personnel against burns.

There are various types of lagging (insulation) materials including asbestos, cork, felt, glass, magnesia, mineral, rockwool, foil, and tar paper. The type used must be determined by the specific need of the job at hand. However, the principles of all insulating jobs are basically the same.

One of the most used types of insulation is known as 85 percent magnesia. This type is very suitable for steam- and hot-water lines, and can be used on other pipes where the temperature does not exceed 600° F. The 85 percent magnesium comes in three different forms: molded, powdered, and blocked. Each is designed for a different purpose. The MOLDED type is used on pipes of various sizes. It comes in 3-foot lengths. Available pipe sizes range from 1/2 inch to 12 inches in diameter. The BLOCK type is suitable for boilers or other places where you have a large flat surface to cover. It is available in various sized blocks. The POWDERED type, when mixed with water to form a paste, is used as a covering for fittings, valves, and the like.

When the insulation to be applied is the molded form of MAGNESIA material, here is the procedure to follow.

Usually molded insulation is split in half and covered with a layer of cloth which may be opened somewhat like a hinge. After the molded insulation is placed on the pipe, an adhesive insulation or wheat paste cement is applied to the loose edge of the cloth which is then pulled tightly around the insulation. After drying, the paste will hold the insulation in place. For added strength, metal bands are placed at frequnet intervals around the insulation. If the insulated pipe is outside, or where it will be exposed to the weather, the insulation should be covered with tar paper. The tar paper should be given a coating of melted tar to give it additional waterproofing quality and hold it in place.

The procedure for insulating with the powdered form of magnesium involves mixing the powder with water to form a mud-like substance of thick consistency. This mixture is then applied with a trowel to the fitting or valve to be insulated. Note: Unions should NOT be insulated unless specified in the specifications.

The method commonly used to insulate fittings consists of first applying a coat of the mud-like mixture, then filling in with small chunks of asbestos. Follow with a second coat of the mixture, building it up even with the rest of the insulation. Now add a covering of canvas — and the fitting is insulated.

HAIR FELT and tar paper provide an excellent insulation for cold-water lines. In applying this type of insulation, first wrap a layer of tar paper around the pipe, then follow with a layer of hair felt, tying each layer separately with any type of string or cord. Repeat this operation until you have three layers of felt and four layers of tar paper. Complete the operation by adding a layer of water-proof paper.

CORK pipe insulation is made from granulated cork. It is the bark taken from cork trees and granulated, or ground, and then pressed into molds of various pipe sizes or blocks. Cork covering for pipe is furnished in half sections so that installed piping can be covered. This insulation material is well-suited for cold water and refrigeration lines. However, it should be coated with an approved vapor barrier, to prevent moisture from entering into the insulation material itself and causing it to lose its insulation value or come apart.

At some locations, it may be necessary to insulate all piping, including belowground as well as aboveground piping. The type of insulation used for belowground piping is similar to that for aboveground. Where insulation is required for belowground piping, however, it requires more protection from the elements. In some cases a poured concrete trench is made and the pipes are installed inside of that. In this case, molded pipe covering or loose mineral wool or glass wool is used. However, the insulation still requires protection from ground or rain water. This is accomplished by coal tar being used as a sealer or by wrapping with tar paper or aluminum foil.

ROUGHING-IN

Roughing-in is just as important with water systems as with sewer systems. As pointed out earlier in this chapter, roughing-in has to do with the water supply and waste pipes which make up that part of the plumbing system usually concealed in the walls and floors, and usually installed while the building is being framed. At this point we are primarily interested in roughing-in as applicable to the water service to fixtures and other service connections.

Plumbing fixtures are the receptacles into which wastes are put prior to discharge into the sewer. There are many and varied different types and styles of fixtures, some being general

Table 4-1. — Plumbing Fixture Unit Values

Fixture	Units
Lavatory or wash basin	1
Kitchen sink	2
Bathtub	2
Laundry tub	2
Combination fixture	3
Urinal	5
Shower bath	2
Floor drain	1
Slop sink	3
Water closet	6
180 square feet of roof drained.	1

54.320

in nature while others are made special to suit a particular application, i.e., hospitals, prisons, or other similar institutions. Many plumbing fixtures are constructed solely of vitreous china, or of iron or steel and porcelain covered. Utmost care must be exercised in handling, installing, and repairing such fixtures. Military installations usually are planned to house large numbers of men and the plumbing fixtures ordinarily are installed in batteries. The actual installation of the fixture is a hard and fast rule; either the manufacturer will state how it is to be done or specifications will state the so-called "roughing-in" measurements of the particular type fixture in question. There will be times when it will be necessary for you to design and lay out a fixture or battery of fixtures, and such things as the waste size requirements, water supply requirements, and stack size requirements must be known and worked into the design.

Standard plumbing fixtures are individually tested and the amount of liquid waste which could be discharged through their outlet orifices in a given interval is measured. It was found that the wash basin, which is one of the smaller fixtures, could discharge through its waste one cubic foot of water per minute. This started the basis for the fixture unit system. One fixture unit thereby being in known liquid contents of 7 1/2 gallons (1-C.F.) of water per minute. The fixture unit value for different plumbing fixtures is indicated in table 4-1.

Each plumbing fixture is equipped, of course, with a waste pipe of sufficient capacity to carry

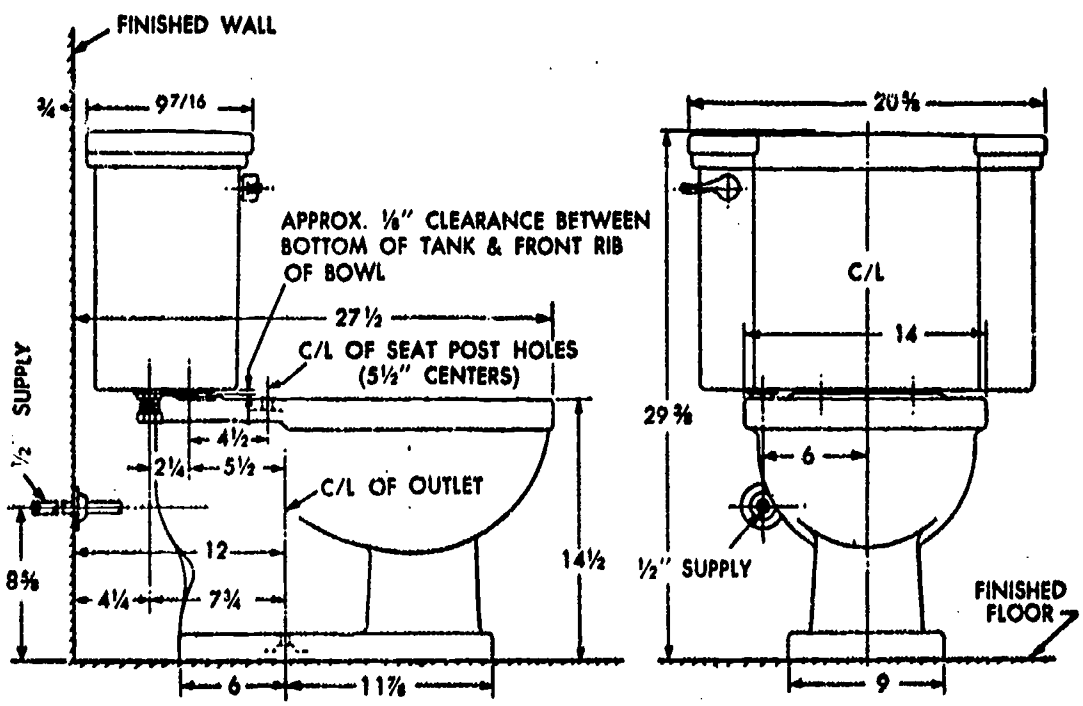

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Figure 4-53. — Rough-in measurements of one type of water closet.

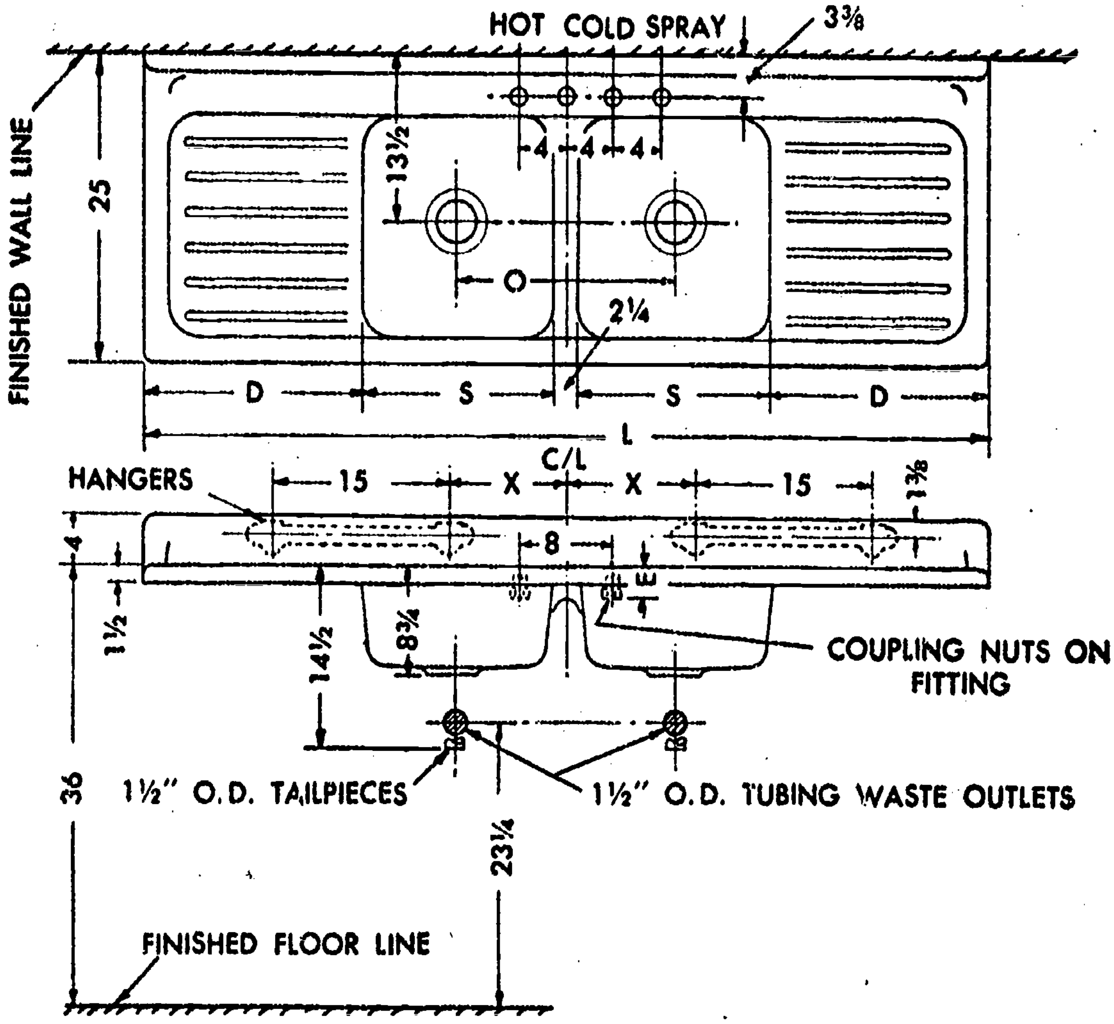

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Figure 4-54. —Rough-in measurements of one type of sink.

off quickly and quietly all water that is supplied to it. A plumbing fixture must also be furnished with water at a rate of flow which will fill it within a reasonable time.

As a general rule, the following supply pipe diameters are recommended: water closet tank, one-half inch; water closet flushing valve, 1 inch; lavatory, one-half inch; urinal equipped with a flushing valve, 3/4 inch; laundry tube, one-half inch; kitchen sink, one-half inch; slop sink, one-half inch; drinking fountain, one-half inch; and shower one-half inch.

Figures 4-53 through 4-58 show single line drawings of the roughing-in measurements for various fixtures. Remember that before roughing-in measurements can be determined, it is essential that you know the exact fixtures to be installed.

Service connections for steam radiators will depend upon the sizes to be installed and the location of each. The same will hold true for water tanks used for storage or heating purposes.

PLUMBING FIXTURES

When roughing-in has been completed, it will be easy for you to install the plumbing fixtures and the necessary trim work. Instructions will be given here on the installation of various types of fixtures and accessories. We cannot include every type of fixture you will install; but if you learn to install those covered, you should have little difficulty with other types.

Water Closet and Accessories

A water closet with tank installed is illustrated in figure 4-59. To install a water

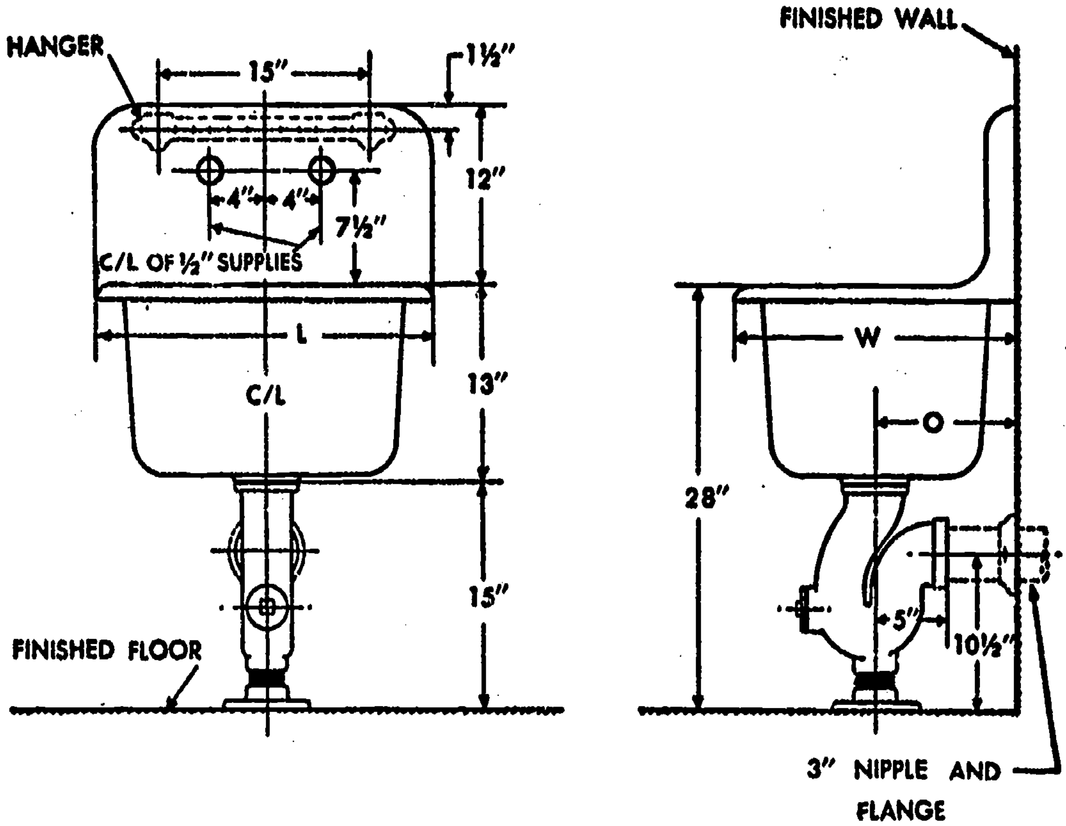


Figure 4-55. —Rough-in measurements of service sink.

closet, the following procedure may be used as a general guide:

1. Slip the water closet flange over the closet bend and slide it down until it is level with the finish floor.

2. Prepare the joint for a lead-calked joint; pour and calk the water closet flange to the closet bend.

3. With a hammer and cold chisel, break off the portion of the closet bend which projects above the water closet flange. Exercise care not to break the closet bend below the flange.

4. Place the two brass closet holddown bolt heads in the slots of the flange.

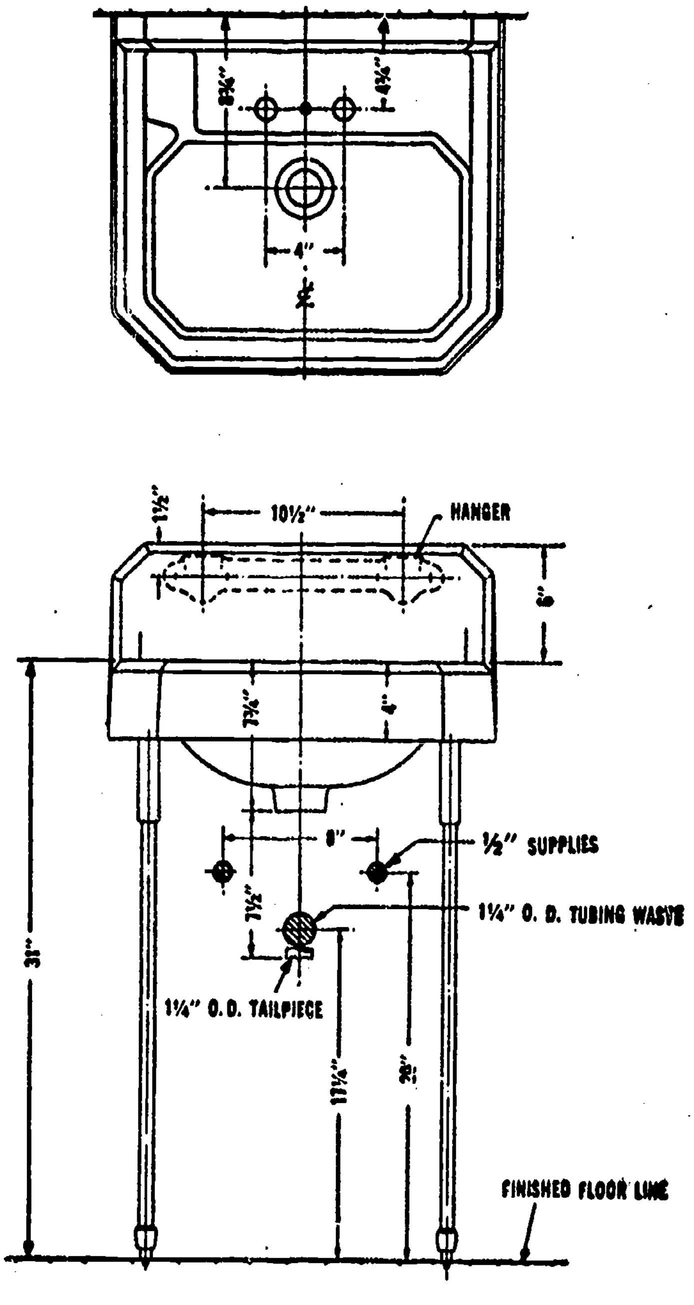
5. On the bottom of the water closet, slip the preformed sealing ring over the horn to form a sealing gasket for the water closet against the face of the flange. Do not use putty as it will dry out, leaving a possible sewer gas leak.

6. Turn the water closet bowl right side up and set it on the flange with the horn projecting down into the flange. In setting the bowl on the flange, guide the two holddown bolts up through the bolt holes on either side of the base of the water closet.

7. Install nuts on the holddown bolts and tighten them alternately. Do not overtighten them as this may crack the base of the water closet.

Cold water for flushing can be supplied to a water closet by a flush valve or a closet tank. Figure 4-59 shows a closet tank installed. It is simply held in place by screws in the top of the back of the closet tank, and is connected to the water closet by a water closet elbow. Figure 4-60 shows the breakdown of a water closet elbow.

When a flush valve is used, a tank is not necessary. In addition to water closets, flush valves may also be used on urinals and other fixtures. Flush valves are of two general types: the diaphragm type and the piston type. Although there are many variations and elaborations in design, the basic operating principles are essentially the same. A particular



54.61
Figure 4-56.—Rough-in measurements of a lavatory.

advantage which flush valves offer over flush tanks is that they require less water for flushing. The interval between flushing operations is also less with flush valves than with flush tanks. Actually, after flushing the fixture it serves, the flush valve is ready for reflushing within a matter of only a few seconds.

A detail of a diaphragm-type flushing valve is shown in figure 4-61. The diaphragm-type valve consists of an upper and a lower chamber. These chambers are separated by the diaphragm and relief valve. The lower chamber is connected directly to the incoming water supply. This incoming water is the flushing water and also the water that shuts the valve off after the flushing period. Shutting the valve off is accomplished by the diaphragm and the water pressure in the upper chamber. Water is forced into the upper chamber through a small orifice (hole) in the diaphragm. Water pressure passing through this orifice into the upper chamber creates the pressure required to force the diaphragm down. This shuts off the flushing water. By moving the flushing handle the relief valve tilts open. This decreases pressure in the upper chamber to less than that of the incoming and flushing water. The action allows the flushing water pressure to raise the diaphragm off the flushing seat and recycle.

Figure 4-62 shows a piston type of flush valve. With this type of flush valve, the piston is drawn up when the flushing begins, then returns to its closed position by the filling of the upper chamber through the orifice tube.

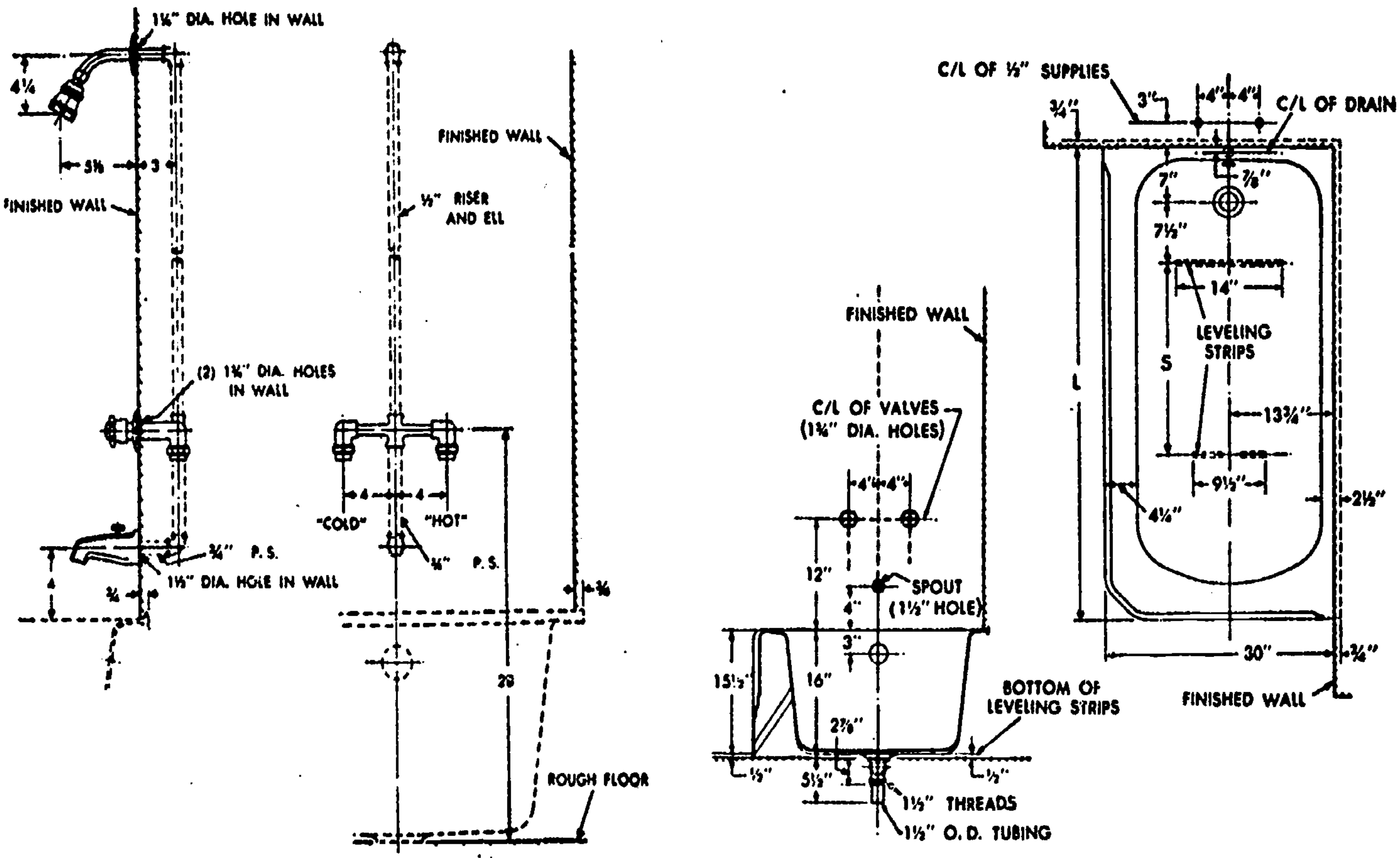
Flush valve assemblies on urinals and water closets may be protected from unnecessary damage and wear by installing a grip handle or guard firmly over the handle housing. (See fig. 4-63.) This grip handle will increase the operating life of flush valves and thereby reduce service calls on the repair of flush valve assemblies and plumbing fixtures.

Sinks

Sinks are made in different patterns, each intended to serve specific purposes. Two common types of sink are the kitchen sink and the slop sink.

The KITCHEN sink is available in different sizes and may have either a single bowl or a double bowl. It is made of either enameled steel or enameled cast iron.

In the installation of a kitchen sink, it is important that the sink be built into a cabinet or hung from a bracket which is screwed to a mounting board. (See fig. 4-54.) The bracket should be screwed into the mounting board in a position where the sink, when mounted, will be at a convenient height for use. As a rule



54.62

Figure 4-57.—Rough-in measurements of tub and shower combination.

of thumb, the distance between the top of the drainboard and finished floor should not be less than 36 inches.

After screwing the bracket into place, lower the sink into position on the bracket so that the lugs cast into the back of the sink fit down into the corresponding notches in the bracket. Screw the strainer and tailpiece into the sink bowl and connect the trap to the roughed-in waste. To complete the installation, select a suitable faucet, install it on the sink and connect the water supply to it.

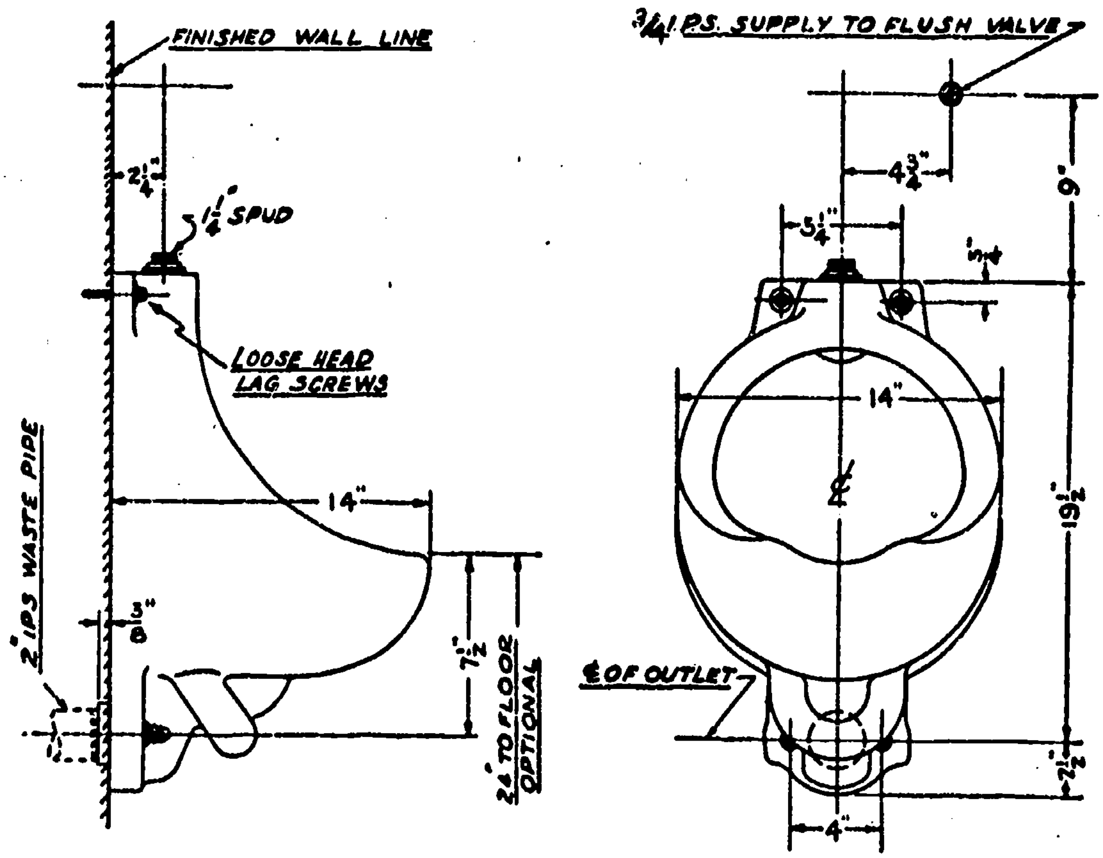
A SLOP SINK, also referred to as a SERVICE SINK, is especially useful for washing purposes with a bucket and swab. It has a very deep bowl and generally is constructed of cast iron and finished in enamel.

The slop sink installation is similar to the kitchen sink installation. The slop sink is also mounted on a bracket and mounting board. (See fig. 4-55.) In addition to the hanger, the slop sink also has a built-in adjustable stand trap which bolts to the floor and provides a pedestal support. The stand trap should be adjusted to take most of the weight off the hanger and prevent the unit from sagging. After the fixture has been set in place and the waste supply has been connected, suitable faucets are installed and connected to the water supply, and the unit is ready for use.

Lavatories

The wall-hung lavatory, which is the most common type in use, is suspended from a bracket screwed to the wall. It may, or may not be supported (additionally) by legs. Figure 4-56 shows a view of a wall-hung lavatory. To install this fixture, follow the steps below, in the order given.

1. Mark wall at correct height for lavatory and secure hanger to the wall.



54.63

Figure 4-58. —Rough-in measurements of a wall-hung urinal.

2. Position lavatory on the hanger.

3. Using a basin wrench, install the lavatory faucets.

4. Install P O (that is permanent overflow) plug in lavatory (see fig. 4-64).

5. Connect tailpiece of P O plug to trap for drainage.

6. Connect water supply lines to faucets.

Shower and Tub Combination

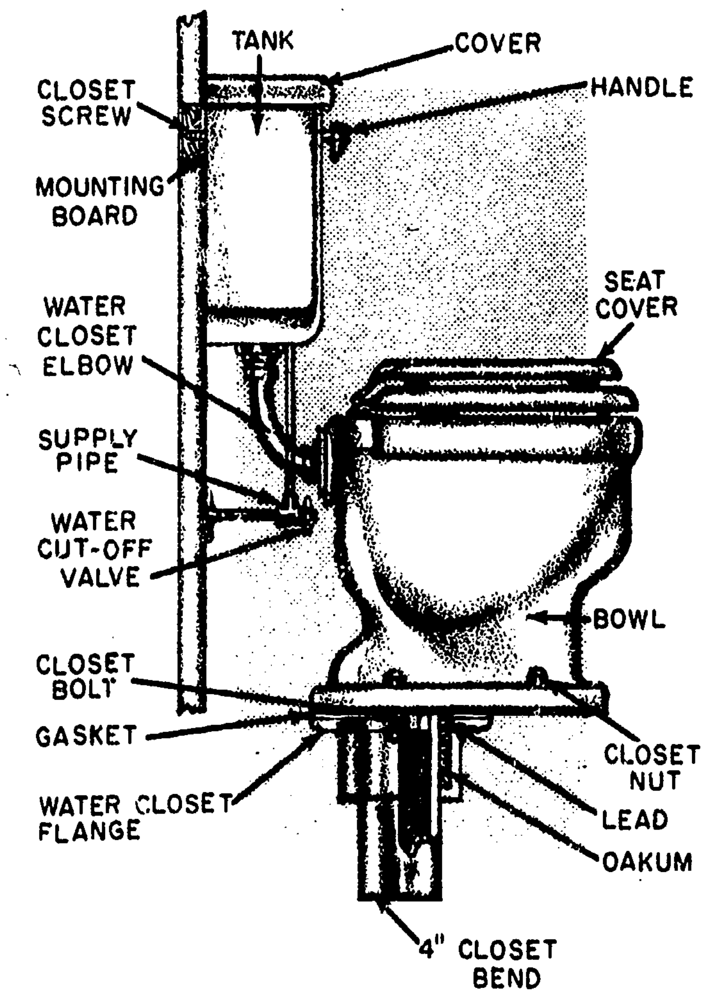
The installation of a shower and tub combination is a simple process. The only pipe that is directly connected to the tub is the 1 1/2 inch drain with the combination overflow. As indicated in figure 4-65, hot and cold water lines, with shower diverter, are installed above the tub.

In making the installation, set the tub in the desired location and level it with leveling strips. At times additional shims or wedges are necessary to level the tub. As the next step, install the drain pipe in the tub. Then connect the drain of the tub to roughed-in P-trap.

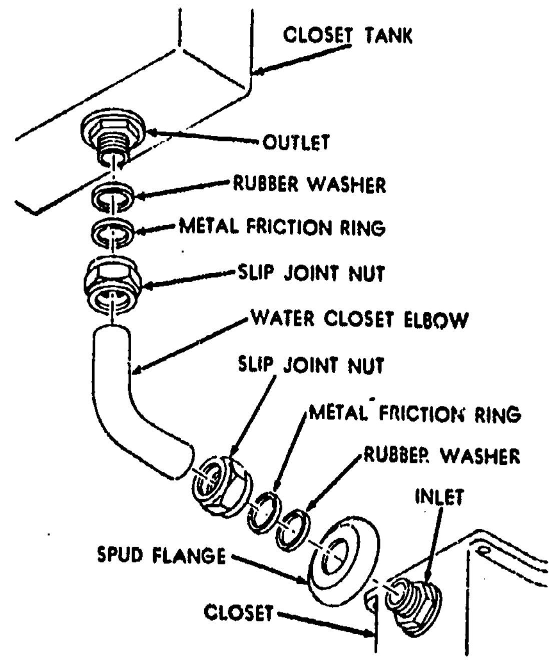
Urinals

Two major types of urinals in use are floor-mounted and wall-mounted urinals. With space being limited, we will only consider some of the main items relating to installation of the wall-hung urinal. If you learn to install this type, however, you should have little trouble installing floor-mounted urinals.

When setting the wall-mounted urinal (see fig. 4-58) the rough-in of the waste pipe must be at the correct height so that the urinal will be easily accessible to the user after installation. The lip of the urinal should be from 20 to



54.64
Figure 4-59.—Detail of water closet and wall-hung tank in place.

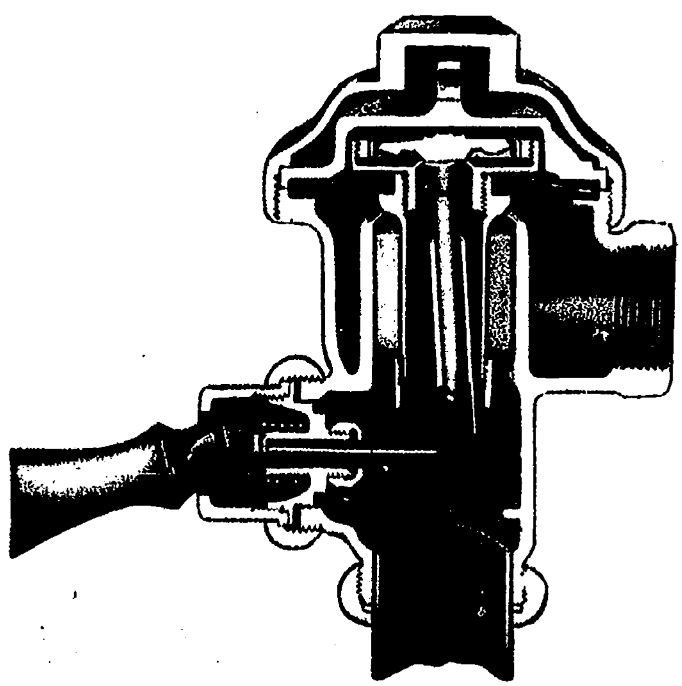


54.65
Figure 4-60.—Detail of water closet elbow.

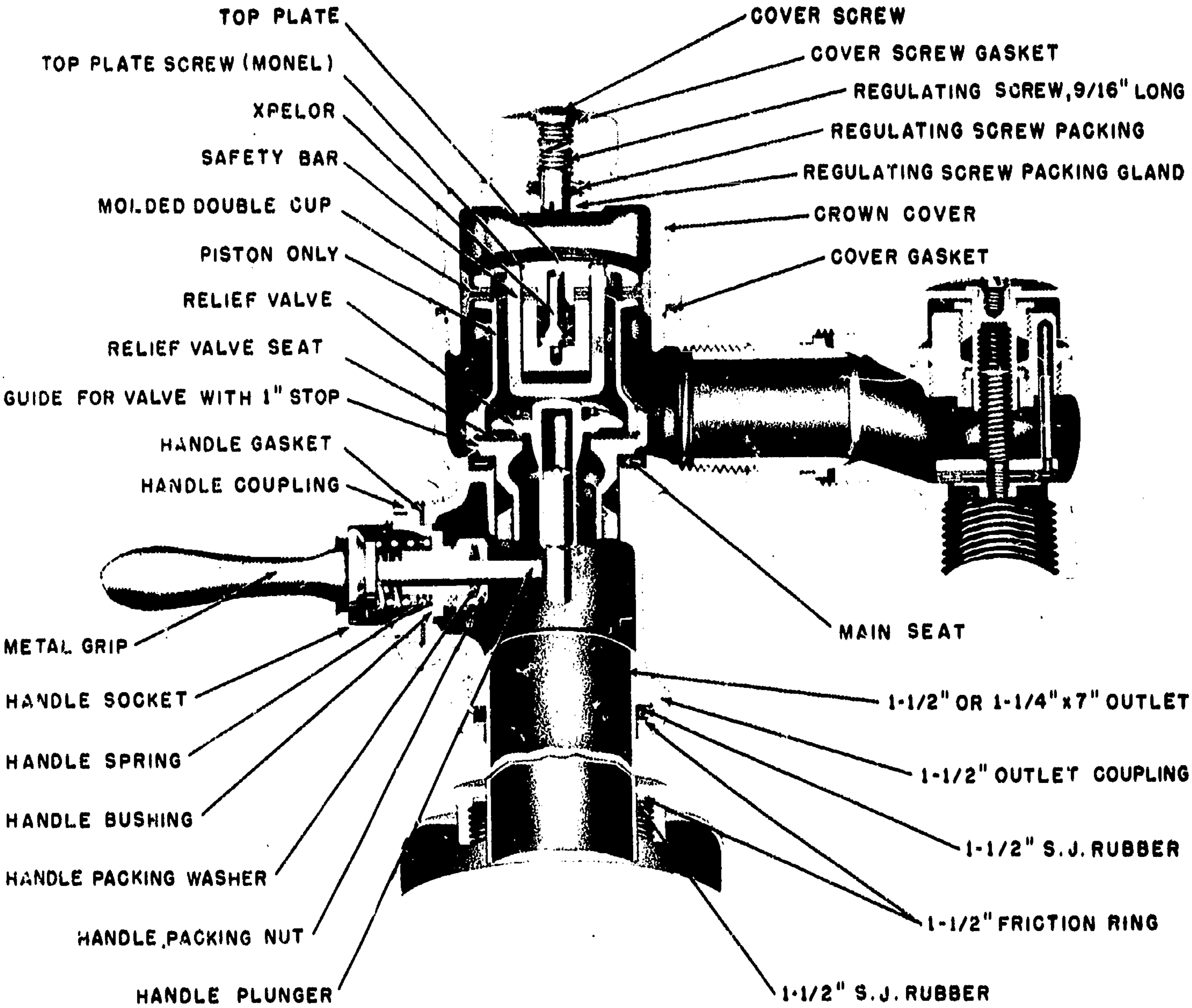
25 inches from the floor. If the rough-in already installed in the building will place the height of the urinal above or below these general measurements, the rough-in should be removed and the waste pipe brought in at the proper height. Since the wall-hung urinal sometimes has an integral trap, it is not always necessary to provide the waste pipe with a separate chrome or iron trap. Where the urinal is to hang on the wall by screws, a mounting board must be installed to provide firm support for the urinal. The last step in the installation of the wall-hung urinal is the connection of a flushing mechanism such as the diaphragm type urinal flushing valve.

Drinking Fountains

All types of drinking fountains should be installed with the orifice located from 30 to 40 inches above the floor, depending upon the



54.66
Figure 4-61.—Diaphragm type of flushing valve.



64.207

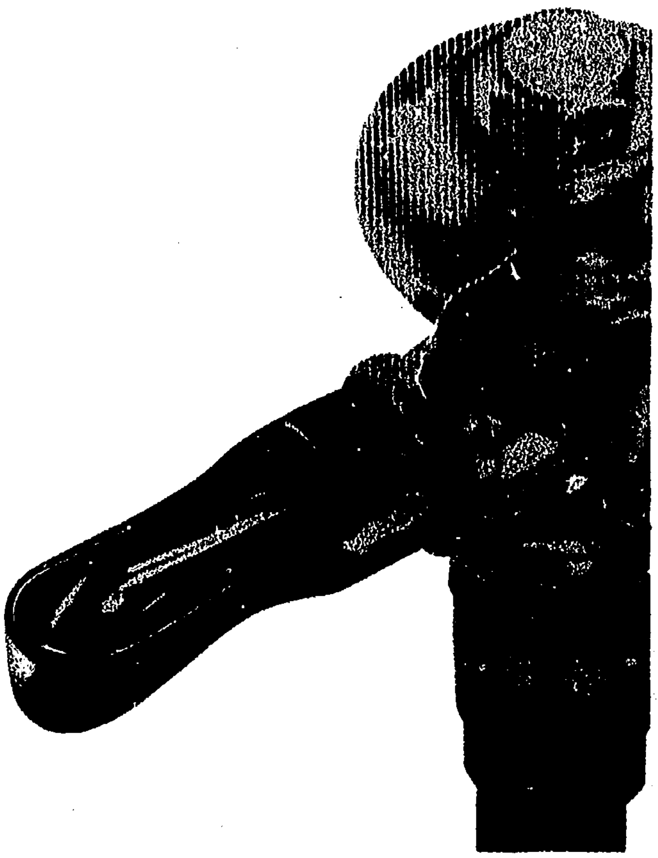
Figure 4-62. — Piston-type flushing valve.

general height of the persons who will be using it. One type of wall-hung drinking fountain is shown in figure 4-66. The mounting of the fixture should be sturdy and capable of sustaining considerable weight in addition to that of the fixture. Most drinking fountains must be installed with a 1 1/4-inch P-trap underneath the waste, but a few are available with integral traps. The electrically cooled drinking fountain requires an electrical outlet nearby for power. Because of the many variations in style of drinking fountains, the manufacturer's installation procedure and specifications should be followed in each case.

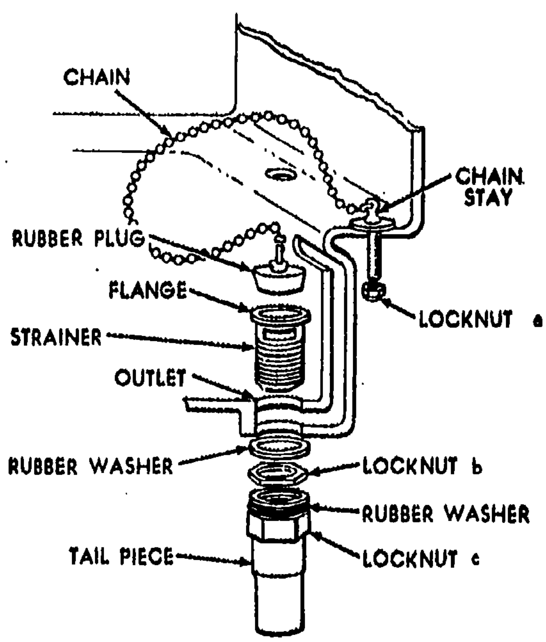
Water Heaters and Tanks

The storage type of hot-water heater is commonly used to furnish laundries, hospitals, barracks, and galleys with hot water. These heaters consist of a horizontal or vertical tank with a steam-heating element near the bottom. A horizontal tank with a typical method of connecting a heater is shown in figure 4-67.

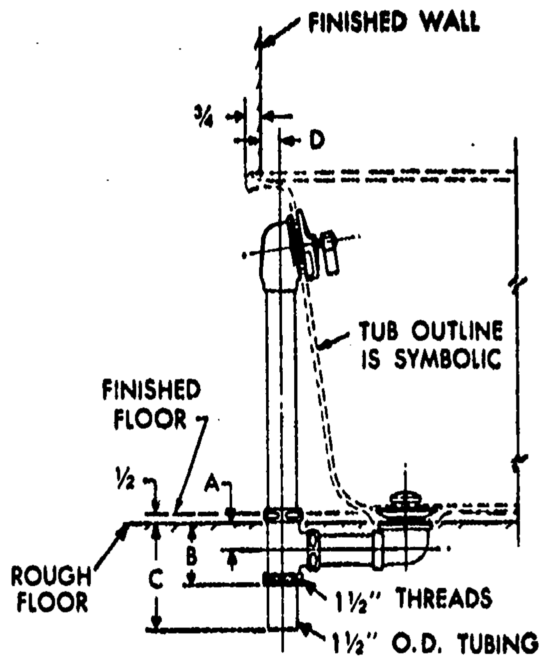
When installing this type of heater, follow the plans and specifications for your installation. Note, however, that two devices used for controlling the water and steam are the temperature controller (or regulator) and the steam



54.208
Figure 4-63. — Flushing valve guard.



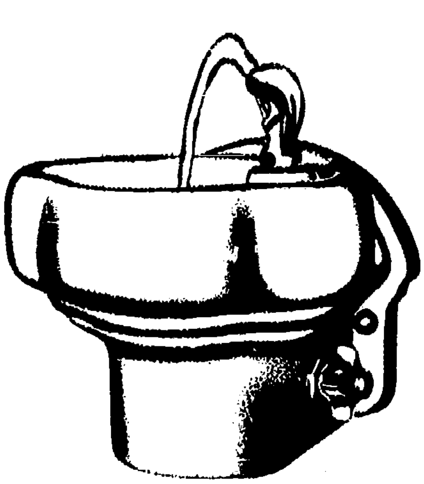
54.67
Figure 4-64. — Detail of P O plug.



54.68
Figure 4-65. — Drain with combination overflow.

trap. In view of the importance of these devices, some attention will be given them in this training manual. A brief treatment on the temperature controller is presented below; information on steam traps is given in chapters 15 and 16.

A TEMPERATURE CONTROLLER consists of a regulating valve, a temperature bulb, a metal bellows to operate the valve, and the necessary tubing to connect the valve to the



54.69
Figure 4-66. — Wall-hung drinking fountain.

bellows (see fig. 4-68). The temperature bulb, tube, and bellows are partially filled with a liquid suitable for the temperature the valve is to control.

The bulb is inserted wherever temperature is to be controlled, as in the feed-water heater or hot-water heater. The valve is mounted in the steam or hot-water line supplying the heat. The liquid in the bulb expands and vaporizes when heated, and builds up a pressure in the metal bellows, which is resisted by the spring. Any change in pressure in the system, due to a change in temperature of the bulb, causes a corresponding movement of the valve to restore the temperature to the desired point.

COMPRESSED AIR SYSTEMS

The installation and maintenance of air compressors, as required for piping systems, are primary responsibilities of the Utilitiesman. Some useful pointers that will assist you in handling these duties are given below. In this discussion we are especially interested, however, in low-pressure compressed air systems since this kind is likely to be of particular concern to the UT. (You will note that only a brief treatment on air compressor systems is given here. In that case, let us remind you that information on compressor components and other topics relating to air compressors is presented in chapter 6 of this training manual.)

The size of the air-intake piping should have an area equal to the compressor air-intake connection provided that the equivalent length of pipe is not over 10 feet; the velocity of the incoming air, however, should not exceed 2,800 fpm (feet per minute). The pipe should be increased one standard pipe size of 1 inch in diameter in the case of large pipes for each equivalent 10 feet of additional length. All bends should be long-radius elbows.

Air supply to compressors having capacity of 500 cfm (cubic feet per minute) and over should be taken from outside the building to obtain air as cool as possible. The air intake should be located as far as possible from ashbins, coalbins, and other dusty places, and from steam exhaust heads and the fan outlets of of paint spray booths. The intake should be 8 or 10 feet above the ground to avoid taking in air containing dust or other impurities.

An effective air filter always must be used on the intake to keep the compressor free of

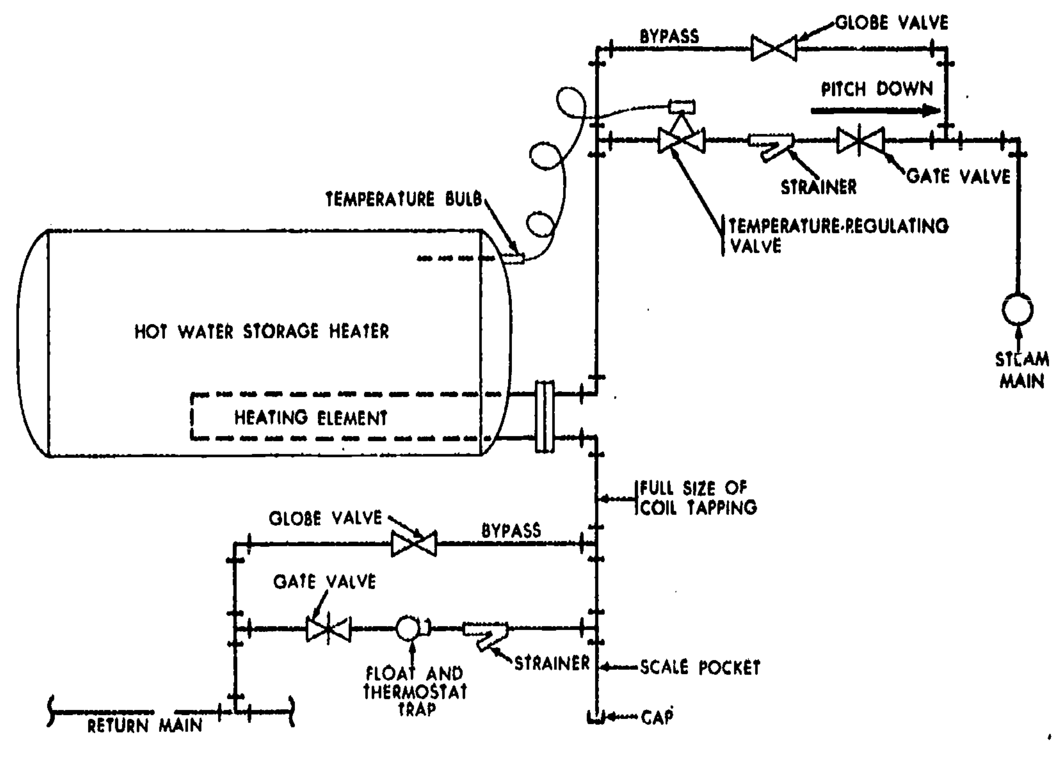


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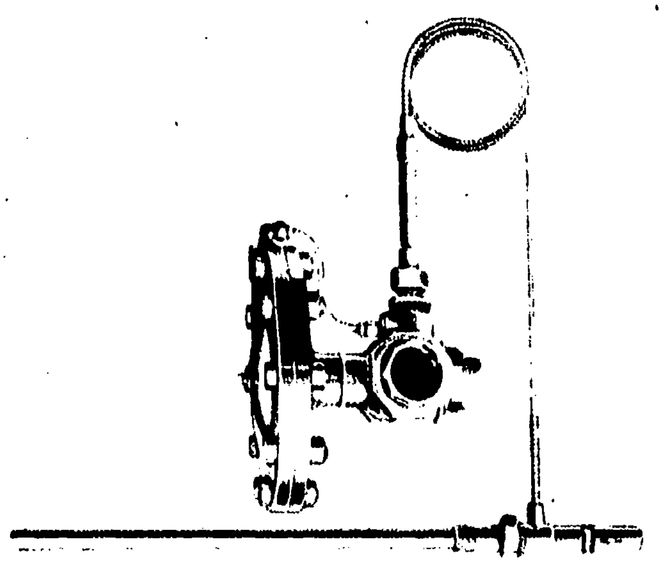
Figure 4-67. — Typical steam and return piping for hot water storage heaters.



54.71
Figure 4-68. — Temperature regulator.

abrasives that may cause sticking valves, scored cylinders, and excessive wear.

In low-pressure (and medium-pressure) systems, black steel pipe in appropriate thickness is generally used for air distribution. For special conditions, stainless steel pipe, brass pipe, and copper tubing with appropriate fittings are also used. Flanges should be used to connect piping to removable equipment, except that the smaller sizes of pipe may have screwed fittings.

Air piping should be pitched slightly, preferably in the direction of flow (3 in. per 100 feet) to collect condensation. All piping must be dripped at the low points to automatic traps or to pockets with automatically operated drain valves.

In large shops or buildings, pipelines that distribute air to numerous branches or service outlets should form a closed loop to encircle the area or interior of the building, so that maximum pressure at branches and outlets may be achieved. Connections for branch lines and outlets should be at the top of the distribution pipeline to prevent carryover of the condensed moisture.

Automatic moisture traps are the most practical means of removing the condensate. The bottoms of scale and drainage pockets should have valves to facilitate cleaning.

Traps are effective, however, only when the air has been cooled and the moisture has precipitated. When no aftercooler is used at the compressor, and the flow of compressed air is infrequent because of intermittent use, cooling may be considered satisfactorily accomplished by radiation from the pipe.

It is essential that air distribution lines be kept absolutely free from leaks. This should be done by systematic inspection of systems at all installations using air distribution systems. To emphasize the need for inspection, note that a 1/16-inch hole on an air line carrying 100 psi of air will result in the loss of 2,000,000 cubic feet of air per year, or the entire output of a 500 cfm compressor for nine 8-hour days.

On a regular basis, traps, strainers and filters should be cleaned and checked for proper operation. See that these parts are kept free of dirt, moisture, corrosion, and so on.

As a safeguard against corrosion, the external surfaces of air lines should be protected by corrosion-proof paint. This is especially important when they pass through damp tunnels or other humid places or are exposed to weather.

In addition to the safety precautions applicable to steam distribution, a thorough and periodic inspection of all airhoses should be made to assure their integrity against bursting. To prevent damage to personnel and property, airhoses must be properly secured and protected so that they do not whip. If such danger exists, it is recommended that a suitable flow-limiting device be installed immediately ahead of the hose or pipeline in question.

RECEIVERS should be equipped with safety valves, and the valves should be tested at regular intervals. Receivers also must be given the same care, inspection, and tests as are given to water tanks and other unfired pressure vessels. They should be tested hydrostatically at least twice a year under a pressure of 1 1/2 times their working pressure.

Because of the multiplicity of control, regulating, and unloading devices installed on various compressors, detailed instructions for their adjustment and care cannot be made. Reference should be made to the manufacturers' instruction books for information as to the method of adjustment for these devices. In general, however, changing the setting of the stop-start control on electrically driven compressors is accomplished by shifting the position of contacts on the pressure switch.

SAFETY PRECAUTIONS

1. Keep job clean.
2. Pick up scrap pieces of pipe.
3. Keep all tools and materials off the job when not in use.
4. Keep shop floors dry and clean.
5. Keep stockpile materials carefully braced and blocked, to prevent falling.
6. Lift with legs, not back.
7. Use pipe tongs for carrying heavy pipe sections.
8. Use proper tools for the job at hand.
9. Keep tools in good condition.
10. Use care in handling torches and hot lead.
11. Do not pour hot lead in a wet joint.
12. Use safety goggles, when required.
13. After installing any fixture, test the pipes for leaks and proper drainage before leaving the job.

CHAPTER 5

PLUMBING REPAIRS

Fixing leaky faucets, unstopping clogged sewerlines and fixtures, replacing/defective float balls in flush tanks, and thawing frozen pipes are only some of the jobs that the UT may have in the area of plumbing. Even in the best of plumbing systems, failures can be expected from time to time. This is not surprising in view of the use made of such fixtures as faucets, showers, and water closets. When a failure occurs in the plumbing system, make a special effort to locate the source of the trouble and see that the necessary repair or adjustment is made promptly.

There is a lot to know about plumbing repairs and adjustments. Keep in mind, therefore, that the subject is only covered in part in this chapter. And with space being limited, we cannot attempt here to cover in detail the many varied types of plumbing materials, and their component accessories, produced by numerous manufacturers for Navy use. However, minute detail is not necessary because of readily available excellent instructions, diagrams, exploded drawings, and photographs that most manufacturers provide with their plumbing products; these aids are most helpful in showing how various parts are assembled. In this discussion you will be introduced to various duties which you may have to perform from time to time in order to keep the plumbing system of your activity in efficient operating condition. Use the information given here as a foundation on which to build a wider and broader knowledge of the maintenance and repair phase of the plumbing trade.

Let us emphasize that proper maintenance and upkeep of the plumbing system will save dollars by extending the useful life of fixtures, and by conserving water and utilities. Porcelain-enameled steel surfaces can, by proper care, be made to last 15 or more years. When given proper treatment the period of efficient use of metal faucets, traps, piping, and other fittings may be doubled. Good maintenance of faucets will eliminate dripping and save water. For example, one water faucet, leaking one drop every second, will waste about 2300 gallons of water in a year's time.

Every user of fixtures should be encouraged to assist in maintenance. Placards posted in toilet rooms or other plumbing areas promote good maintenance. These can be cartoons, drawings, or short slogan-type messages slanted toward enlisting assistance of users, and should give telephone numbers to be called if plumbing is found to be out-of-order. Encourage everyone to turn off water faucets.

BREAKS IN WATER SYSTEM

A break in the water distribution system calls for emergency action. To repair a break in the system, in the shortest time possible, you not only need trained men but the necessary materials must be readily available. When a system is broken down, a number of highly undesirable conditions exist. Some of these are:

1. The water supply generally available for fire protection is seriously curtailed or does not exist.
2. Escaping water under pressure may seriously undermine structures, damage foundations, destroy landscaping, or cause erosion.
3. While the pipe is broken, a health hazard exists because the distribution system may be contaminated by external sources.
4. The water demand for normal domestic or industrial use may be sufficient, or the supply may be completely cut off.

To ensure proper maintenance of a water distribution system, charts and maps should be on hand showing existing conditions in all parts of the system. At some activities, records may not be available indicating the exact location of important buried lines. In such instances, steps should be taken to learn their exact location and any changes made should be recorded on a master chart or map. Maps of the entire water system should be available, showing the following locations:

1. Sources of supply. If surface supply, show also the sizes of intakes, cribs, dams, and impounding reservoirs.

2. Wells, pumping stations, and treatment plants.

3. Storage reservoirs and elevated tanks, with capacities.

4. All mains, valves, hydrants, and relief valves, with sizes.

5. Service lines, with sizes and point of entrance to buildings.

At some activities electronic devices may be available for subsurface survey and pipe location work. In some cases it may be necessary to determine points of interconnection, actual diameters of pipes, and the condition of exterior surfaces or coatings. For future use, notations should be made on the maintenance maps or charts that indicate the general condition of the system. Some distinguishing symbol should also be used to show the approximate age of the installation or of any of its parts. If charts and maps are complete and kept up to date, as maintenance steps are taken or repairs are made, they are a great help in maintenance planning. In many cases, too, they may offer clues to the most probable location and causes of trouble.

Periodic FLUSHING of the entire system through hydrants and blowoffs is essential to remove scale and accumulation in pipes and fittings. When performing this operation, start at the hydrants or blowoffs nearest the source of supply to avoid wasting water and to stir up less of the distribution system. Each point should be flushed until the water comes out resonably clear. All valves must be in their normal operating positions before going on to the next point.

Special emphasis should be placed upon flushing dead ends. If flushing does not induce enough velocity to scour mains clean, night flushing with large discharges should be practiced. Night operation lessens disruption caused by shutoffs and decreased pressures.

WATER MAINS

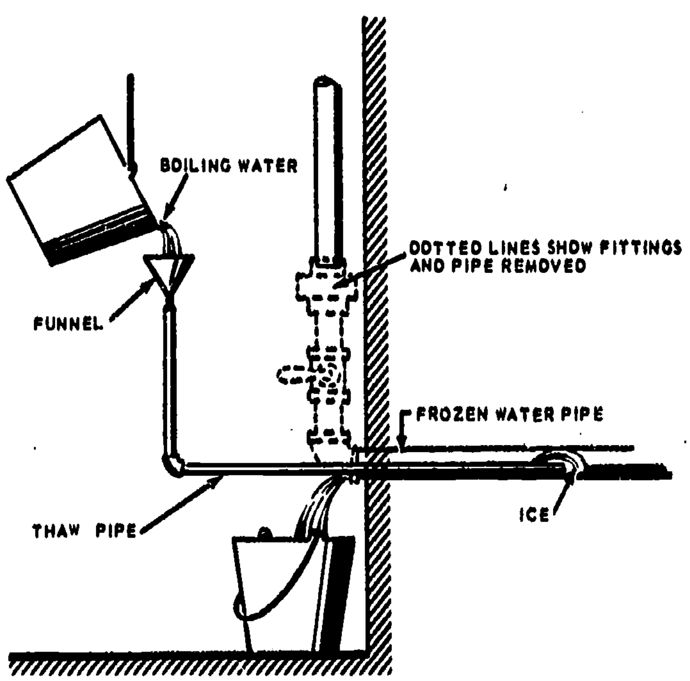
Since water main breaks must be repaired as rapidly as possible, personnel must be trained and repair plans must be made in advance. The following procedures are essential:

1. Post telephone numbers of the Fire Department and key personnel and have alternate personnel available in case members of the regular repair crew cannot be reached at the time of a break. Notify the Public Works Officer at the time the break is reported.

2. Keep the following items available and ready for use at all times: valve keys, hand tools, digging tools, pavement breakers, trench shoring, portable centrifugal or diaphragm pump, floodlights, emergency chlorinator, and calcium hypochlorite powder.

3. Maintain an adequate stock of pipe repair materials and supplies.

As a temporary measure, wood plugs can be used to stop small holes in a main. These plugs can be replaced later with metal plugs, or repairs may be made by other means. Temporary wood plugs may also be used to plug the ends of pipe up to 8 inches in diameter, but such plugs must be braced to withstand existing main pressure.



54.72

Figure 5-1. — Thawing an underground or otherwise inaccessible pipe.

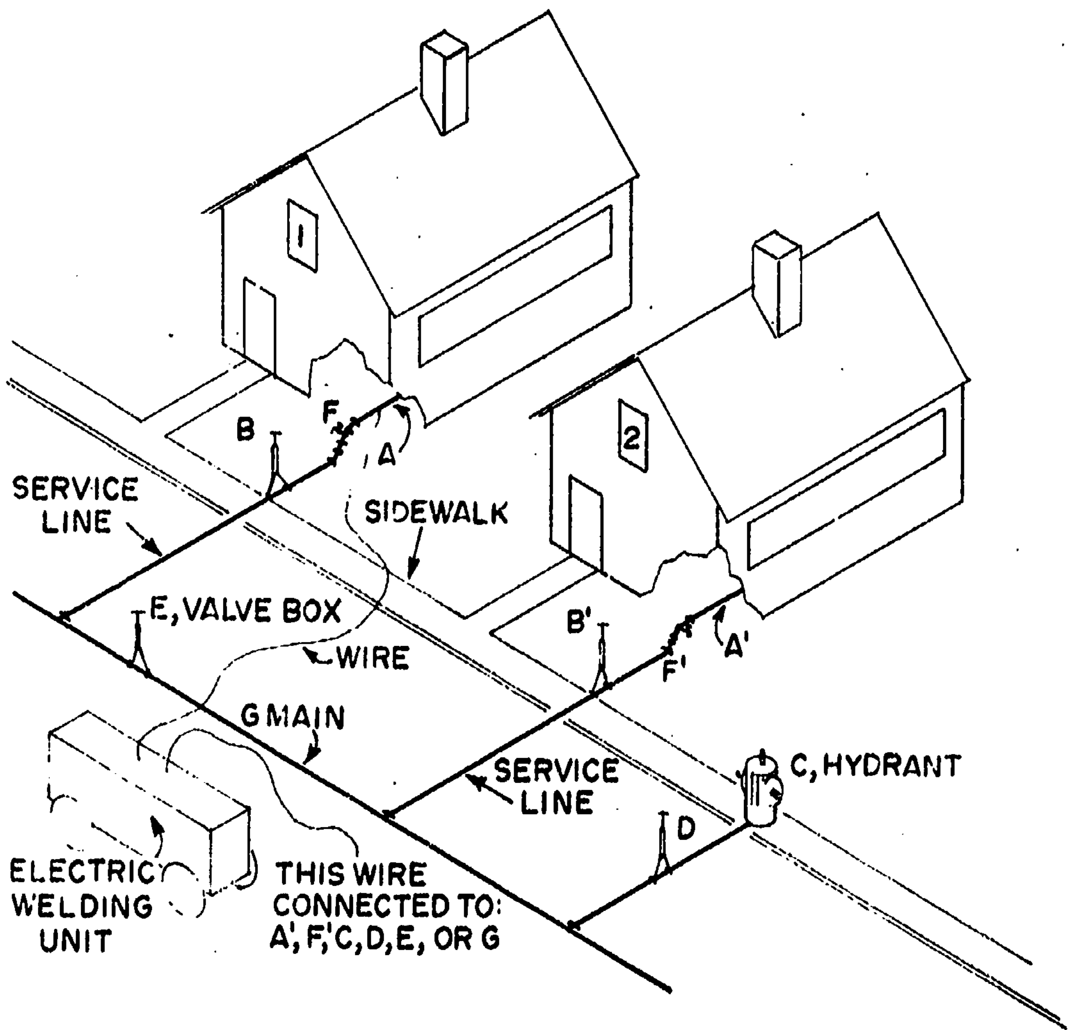


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Figure 5-2.—Connection points for thawing frozen service lines.

After repairs are completed, the main must be disinfected. You will probably recall that disinfection was discussed in chapter 4 of this training manaul.

THAWING FROZEN PIPES

In cold weather, freezing presents a major problem to a water supply system. Because of the lack of protection against freezing, and sometimes regardless of it, pipes frequently may freeze in temperate zones. When this happens, the pipes must be thawed.

Before starting to thaw a frozen pipe, open faucets affected by the freeze. Frozen pipes can be thawed by applying heat at the lowest open end of the frozen section. (DO NOT start in the middle of a frozen section as a pocket of steam could develop and an explosion or damage to the pipe occur.) Where there is no danger of fire, satisfactory results may be obtained simply by heating the pipe with a blowtorch-playing the flame on the outside of the pipe. Instead of a blowtorch, a burning newspaper or candle may be used in this same manner.

In thawing frozen water pipes or heating pipes inside buildings, use hot water. DO NOT use an open flame. A safe method is to wrap the frozen section of the pipe with cloths and pour hot water upon them until the ice gives away. Harm to the floor may be avoided by catching the water in buckets or long pans, or by covering the floor with heavy rags or rugs which will absorb the water.

A good method of thawing water pipes which are underground or otherwise inaccessible is indicated in figure 5-1. In using this method, remove the fittings (see illustration) and insert one end of a small pipe (a tube also will do) in the frozen pipe. Now add an elbow and piece of vertical pipe to the outer end of the thaw pipe. Place a bucket under the opening to the frozen pipe and insert a funnel in the open end of the vertical pipe (see fig. 5-1). With that done, start pouring boiling water through the funnel and into the pipe. As the ice melts, push the thaw pipe forward. Where necessary, additional pipe can be added at the outer end until a passage is made through the ice.

Withdraw the thaw pipe quickly after the flow starts and do not stop the flow until the thaw pipe is fully removed and the pipe cleared of ice.

Instead of a funnel, a small force pump may be used. You will find it useful for thawing a long piece of pipe. If available, you can use steam in place of hot water.

We might point out further, that the above method can be used without the elbow and piece of vertical pipe shown in figure 5-1. Simply connect the funnel to the outer end of the thaw pipe with rubber tubing. Have the tubing long enough that you can hold the funnel above the level of the frozen pipe. This is necessary to give the hot water a head, thus forcing the cooled water back to the opening where it will run out into the pail. Hence, the advantage of the elbow and vertical pipe is that they increase the head of the water and provide added convenience when using the funnel.

ELECTRICAL THAWING

Electrical thawing of frozen service lines is quick and relatively inexpensive. The electrical current for the thawing operation consists of a source of current (a direct-current generator, such as a welding outfit, or a transformer connected to an a.c. outlet), and two insulated wires connecting the current source and the pipe (see fig. 5-2). Only qualified personnel should be assigned the responsibility for the use of powerlines as a source of current. As current flows through the pipe, heat is generated and the ice within the pipe begins to melt. As the water starts to flow, the rest of the ice is progressively melted by contact with the flowing water. The wires from the current source may be connected to nearby hydrants, valves, or exposed points at the ends of the frozen sections.

Some data concerning current and voltage required for electrical thawing of various sizes of wrought-iron and cast-iron pipes are presented in table 5-1.

Table 5-1.—Relation of current and voltage required for thawing

Type of pipe	Pipe size (in.)	Pipe length (ft.)	Approximate (volts)	Approximate (amps.)[1]
Wrought Iron	3/4	600	60	250
	1	600	60	300
	11/2	600	60	350
	2	500	55	400
	3	400	40	450
Cast Iron	4	400	50	500
	6	400	50	600
	8	300	40	600

[1] USE NO MORE THAN 100 AMPERES ON LEAD PIPES WHICH HAVE LEAD FITTINGS OR ANY SOLDERED JOINTS.

54.12

The time required for electrical thawing varies from 5 minutes to over 2 hours, depending on pipe size and length, intensity of freezing, and other factors. Best practice is to apply current until water flows freely.

Precautions

Some important precautions to be carefully observed in electrical thawing are given below.

1. The use of higher current than listed in table 5-1 should be avoided. When in doubt, use low current for a longer period.

2. Select contact points on pipe as close as possible to the frozen section.

3. Assure that contact points are free of rust, grease or scale.

4. Remove meters, electrical ground connections and couplings to building plumbing in line to be thawed.

5. If there are gaskets or other insulation at pipe joints, thaw pipe in section between such joints, or use copper jumpers to close circuit across insulated points.

Procedures

The procedures given below may be followed in electrical thawing.

1. DIRECT-CURRENT GENERATOR. To thaw pipe with a welding generator or similar direct-current source, set the generator to correct amperage for pipe to be thawed and connect leads to pipe.

2. ALTERNATING-CURRENT CIRCUIT. Transformers are required to adjust amperage of an alternating-current circuit to the pipe being thawed. To minimize hazards, have a competent Construction Electrician set and connect transformers, make the connections, and assist in the thawing procedure. Where frequent thawing is necessary at different points, the transformers may be mounted on a trailer for ready use.

STEAM THAWING

Steam thawing of frozen systems is slower than electrical thawing and is used only when insulating materials in pipes (plastic, transite, wood), pipe joints or couplings makes the use of electricity impracticable. In steam thawing, a hose connected to a boiler is inserted through a disconnected fitting and gradually advanced as the steam melts the ice.

VARIATION OF WATER PRESSURE

A variation of water pressure can cause much discomfort on the part of persons using the plumbing system. This trouble is what causes the mixture of hot and cold water from a shower to suddenly vary in temperature or rate of flow when water is turned on at another outlet. Failure to remedy this condition might result in somebody getting injured, especially if the variation in temperature is to the scalding point.

When a variation in pressure and water flow occurs frequently, the place to look in locating the source of the trouble is in the water pipes. Check the pipes to see if they are of the proper size in diameter for their length and height as originally installed. Another thing to look for is liming and corrosion inside the pipes. A large enough accumulation of liming and corrosion can reduce the diameter of the pipe and cause inadequate pressure and water flow.

The trouble sometimes occurs after additional fixtures have been installed in an existing system. When this happens, you will probably find that the piping is overloaded as a result of the additional fixtures. A variation in pressure and water flow may also occur if there is excessive friction in the pipe, owing to too many fittings and changes in direction.

If variations of pressure at showers only occur when other outlets are open, you can correct the trouble, usually, by installing automatic mixing valves. The only answer to an increase in the water flow from inadequately sized pipes is to replace them with a larger size.

PIPE LEAKS

When a leak develops at a threaded joint of pipe, one of the most likely suspects is a fractured or ruptured pipe. Fractures often occur at the end of a pipe length owing to strain imposed by vibration of water hammer. But why the end of the pipe? That is because the wall thickness is decreased and weakened by threading. The risk of fracture becomes even greater when the threads are not cut true. In cold climates, freezing sometimes causes pipes to rupture, in which case replacement becomes necessary. A loose or cracked fitting can also cause leakage at the threaded joint of a pipe. These and other common failures which result in leakage in pipes make it important that you always determine the exact location and cause of failure before commencing any repairs to the piping.

LOCATING LEAKS

It is important that you locate and eliminate leaks in the water piping system as quickly as possible to prevent serious damage to footings, walls, floors, plasterwork, and other parts of the structure, and to conserve water. Find leaks by systematically inspecting exposed piping and valves, and by examining walls, floors, and ceilings around concealed piping. In addition, check gauges, meters, and other waterflow recording devices for evidence of abnormal flow, which might indicate loss through leakage.

REPLACING DEFECTIVE PIPE

When the water has been drained from a line, that part of the line in which the leak is located can usually be removed by cutting with a wheel-type pipe cutter. The pipe on either side of the leak is removed to the nearest fitting. The defective section is then cut out and replaced by new pipe. A union is used to make up the joint.

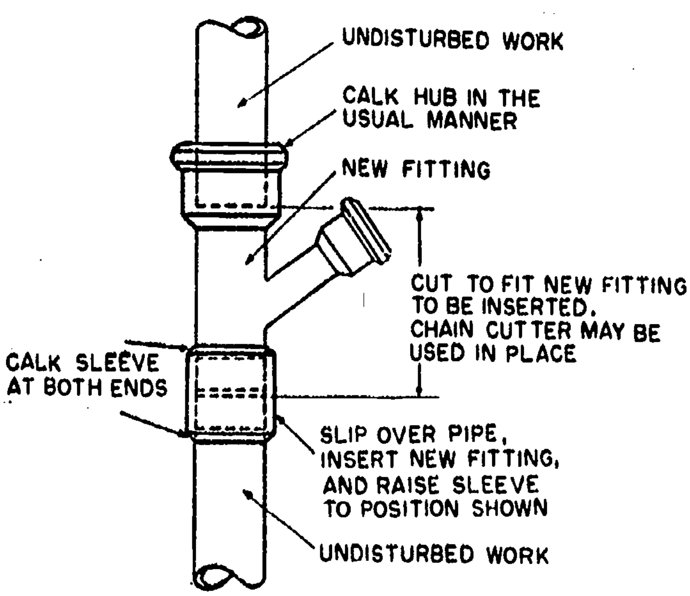
In galvanized pipe installations, where the fittings on either side of the leak are not readily available, the leaking section may be cut out. In this operation one man holds the pipe with a wrench to keep it from turning in the next fitting, as another man cuts a thread on it—while it is in place—using a hand-type pipe threader. The cut-out section is next replaced with a coupling, a pipe section of the required length, and a union.

You may occasionally have to repair leaks in copper piping. In case a leak does occur in a copper pipe the damaged section should be cut out and replaced with a new section, using either soldered or compression type joints as convenient.

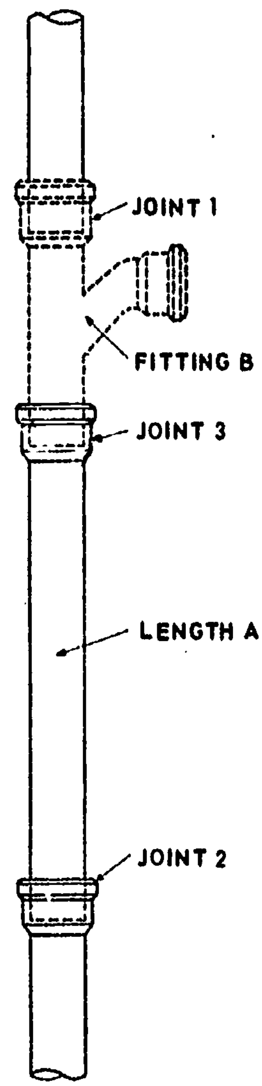
When a piece of cast-iron pipe less than full length is needed for replacement, cut it from a double-hub pipe so that the remaining piece has a hub left for use in other work.

If you need a fitting for a short space, or if existing work cannot be removed easily, use short spigot ends for sleeves. Closely observe figure 5-3, which illustrates the installation of a fitting in a restricted space.

Replace a fitting or insert one into an existing line by following the 4-step procedure shown in figure 5-4.



54.73
Figure 5-3. —Installing fitting in restricted space.



STEP 1. MELT LEAD FROM JOINTS 1 AND 2.
STEP 2. CUT PIPE A TO CORRECT LENGTH.
STEP 3. ASSEMBLE PIPE A AND FITTING B AND INSERT INTO LINE.
STEP 4. STRAIGHTEN LINE AND CALK JOINTS 1, 2, AND 3.

54.74
Figure 5-4. —Inserting fitting in an existing line.

When the job calls for adding connections to an outside vitrified clay sewerline, here is one method which may be used as a guide:

1. Remove a section of the existing sewer pipe long enough to receive a new Y-fitting.

2. Break half of the hub rim of the new Y-fitting, as indicated in view A, figure 5-5.

3. Insert the spigot end of the Y-fitting into the hub of the existing pipe. At the same time, place the remaining half of the hub end of the

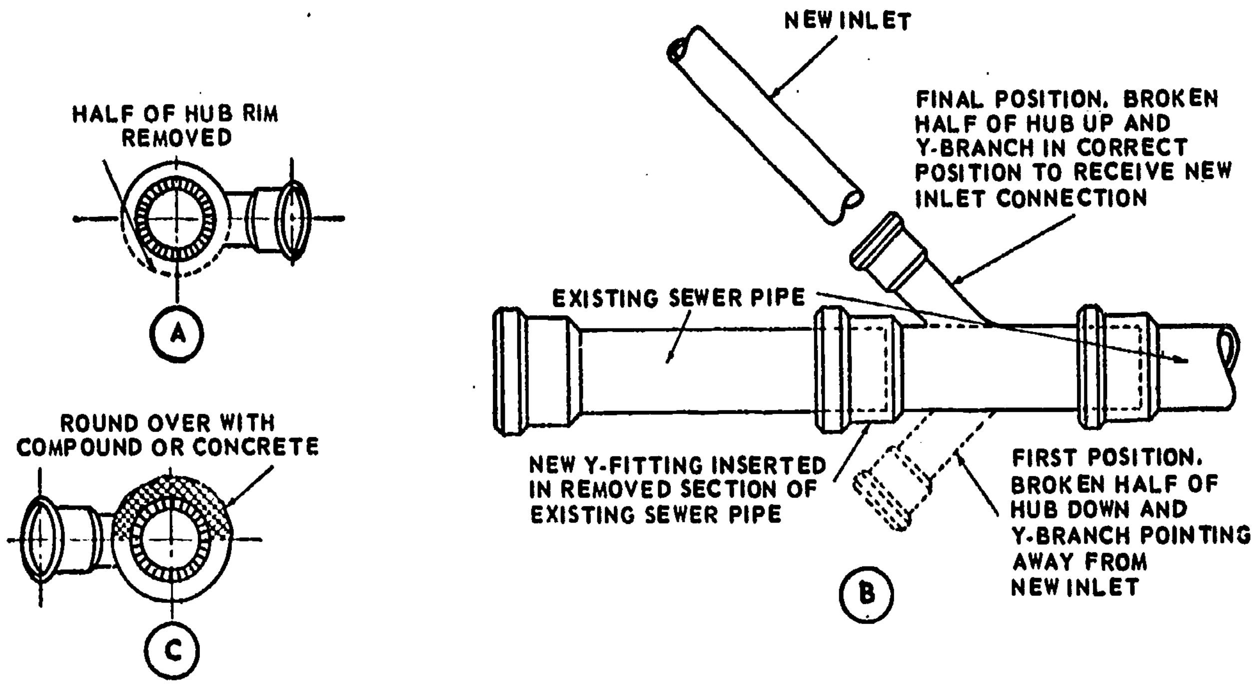


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Figure 5-5. — Adding connections to outside vitrified clay sewer pipe.

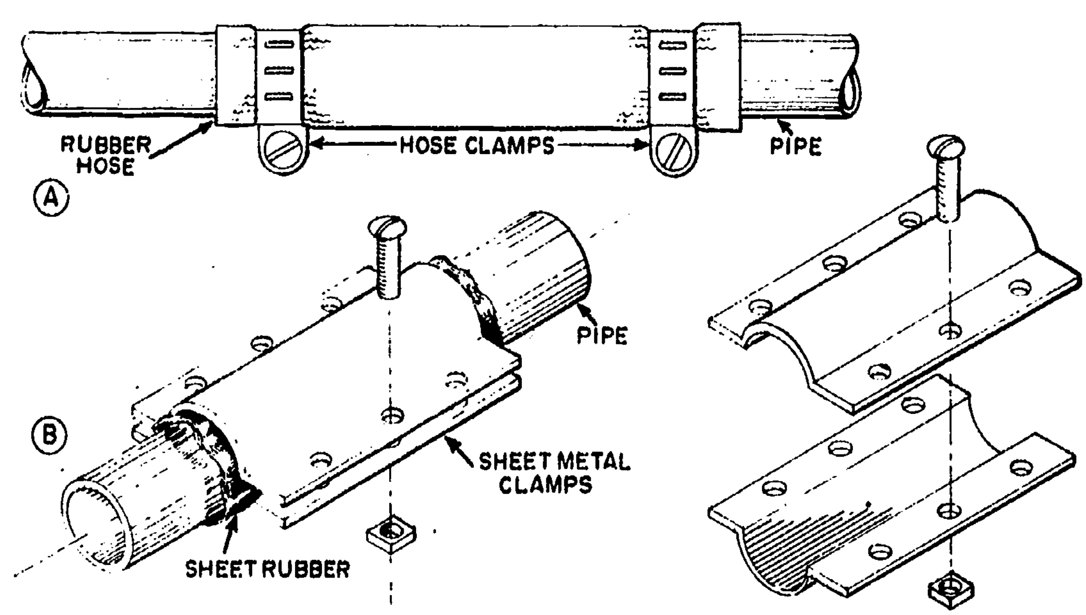

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Figure 5-6. — Temporary-type repairs of leaky pipe.

Y-fitting over the cut end of the existing pipe, with the Y-branch pointing away from the new inlet (see first position, view B of fig. 5-5).

4. Rotate the Y-fitting so that the broken half of the hub is up and the Y-branch is in correct position to receive the new inlet connection (see final position, view B of fig. 5-5).

5. Pour the joint carefully: round over the broken half of the hub with a liberal amount of concrete or mastic compound, as indicated in view C, figure 5-5.

EMERGENCY REPAIR

At times a pipe may start leaking and materials needed to repair it permanently are not readily available. In such cases, it may often be necessary to use a temporary or emergency type of repair. Bear in mind, however, that a permanent-type repair should always be made just as soon as the tools or materials needed for it become available.

One simple method of repairing a leaky pipe temporarily involves using a length of rubber hose. After turning off the water supply, remove the defective section of pipe by cutting with a hacksaw. Then take a piece of rubber hose, slightly longer in length than the section of pipe you removed, and slip it over the ends where the cut was made (see view A, figure 5-6). Make sure the inside diameter of the hose is the same as the outside diameter of the pipe. Hose clamps can be used to hold the hose securely in place.

Another temporary-type of repair for a leaky pipe is to wrap the leaky area with sheet rubber. Then place two sheet metal clamps, one on each side of the pipe, on the sheet rubber covering, as indicated in view B, figure 5-6. Now fasten the clamps with bolts and nuts. Note: Sheet metal clamps suitable for this type of repair job can be made from scrap material obtained from the sheet metal shop. You may want to make up a few of these clamps to keep on hand so that they will be readily available in case of an emergency.

Another temporary measure consists of wrapping electrician's friction tape tightly around the pipe, having it extend about 2 inches above and below the leak. As a simple method, you can also secure the water supply, drain water from the pipe, clean the pipe surfaces thoroughly, apply flux, and then wrap clean copper wire over the rupture and solder.

WATER TANK FAILURES

Where a plumbing system has been in use for some time, two failures in water tanks which should come as no surprise are (1) leaky seams, and (2) corroded areas requiring welded patch plates. To repair a defective seam, first drain the water tank dry. Then clean the surfaces to be repaired until they are bright. By welding or brazing, the leaky portions can then be made watertight.

As an effective tank patch for a large hole, you will need both a temporary and a permanent type patch. One type of temporary patch is a tapered softwood plug. It should be inserted in the hole, and tapped lightly with a hammer until the seal is watertight. Then saw off the top of the plug so that it will be flush with the tank wall.

Next, the area around the plug which will be covered by the permanent patch should be cleaned by wire brushing. The tank should then be drained and you are ready to apply the permanent patch. One type of permanent patch includes a rubber gasket and a metal plate. Rubber sheeting, at least 6 inches by 6 inches and 1/16-inch thick, may be used for the gasket, and should be centered on the plug and cemented with adhesive. The patch plate, of black steel or nonferrous metal, should be of the same material and thickness as the tank wall, and considerably larger than the hole. Cover the hole with the metal plate, keeping an equal overlap around the edges, and braze or weld the plate to the tank, using a continuous seam.

WATER METERS

Careful attention should be given to the maintenance of water meters. The following procedures apply to volume-type meters used as service meters, and for sizes up to 6 inches.

Monthly, make certain that the meter is operating properly. If its operation is noisy, remove and examine the parts, and repair or renew when necessary. Check the dial face for cleanliness, and clean the glass dial cover when necessary.

Annually, make certain that the meter has not been moved out of a horizontal position.

Once a year, in locations subject to freezing temperatures, inspect and clean the meter housing or pit one month before the freezing season begins; also, make certain the meter is protected against possible freezing.

Annually, check the meter for damage by hot water backing up from an improperly installed and/or operated water heater.

At variable periods, clean and inspect the meter for worn parts; change gears and other parts when necessary.

Meters must be calibrated after replacement of worn parts or changing gears.

A schedule for the cleaning and repair of meters is necessary at each activity, and should be based on experience with the meters used in the system and the costs attributable to metering. A large volume of water registered in a relatively short time may cause more deterioration of the meter than a small volume registered over a longer period. The schedule for cleaning and repairs of meters should, therefore, have the following format:

Size (in.)	Registration (cu. ft.)	Service (yr.)
5/8		
3/4		
1		
1 1/2		
2		
3		
4		
6		

Disassemble the meter according to the manufacturer's instructions. Remove sediment; check the interior for corrosion or wear; replace the gears if they are worn; replace the disk or the piston when necessary; clean and brighten the exterior by wire brushing, sand or shot blast, or acid dip. CAUTION: Use acid dip only in accordance with the manufacturer's instructions and Naval Facilities Engineering Command safety procedures.

Note that the frequencies indicated above are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

MAINTENANCE OF FIRE HYDRANTS

Fire hydrant maintenance, an important part of the facility fire protection system, consists mainly of inspection and testing. The replacement of worn parts and seats can usually be accomplished through the top of the hydrant. Special tools are required for replacement operations. For example, you must use ONLY hydrants wrenches on a hydrant; ordinary wrenches may ruin the operating nut. Follow the manufacturer's instructions to ensure use of the proper tools for replacement operations. The UT, accompanied by a fire department representative, may often assist in conducting inspections and tests of fire hydrants, in accordance with command and field engineering office directives. Some of the duties you may perform in maintaining hydrants in good condition are discussed briefly below.

FLUSHING AND TESTING

Proper maintenance of fire hydrants requires flushing and testing at prescribed intervals. A few pointers on flushing and testing are as follows:

1. Hydrant flushing and testing should begin at the valve nearest the source of supply and proceed around a loop, or to the next hydrant, and then proceed to the next loop or hydrant.
2. The hydrant should always be flushed with the valve fully open.
3. Never open or close a fire hydrant rapidly, because the rapid change in pressure creates undue strain on the system and oftentimes it causes underground leaks.
4. The maximum water flow should be measured in the most important feeder and distribution mains at least annually.
5. After a hydrant is flushed, if it is a dry-barrel type inspect the barrel to make certain the water drains out of the barrel. When a hydrant does not drain properly, open the hydrant one or two turns with the hose outlet closed. If this operation is not successful in opening the drain hole, the hydrant must be dug up sufficiently to expose and clear the drain hole with a rod. There are a few hydrant designs that can be disassembled and the rod driven through the drain hole from the inside. (See the manufacturer's instructions.) In cold climates, where freezing occurs, dry-barrel hydrants are used. Where ground water backs up into the barrel through the drain hole, the hole should be plugged and the barrel pumped out after each use of the hydrant.
6. If repairs require the shutting off of the water supply in any area, the installation FIRE DEPARTMENT must be notified IMMEDIATELY; and, the users on that part of the system should also be notified.

COLD WEATHER INSPECTIONS

In sub-zero weather, weekly inspections of hydrants near important structures should be made: other hydrants should be inspected monthly. Do not flush hydrants on such inspections.

Frozen hydrants are tested by placing an operating wrench on the nut and turning slightly. If it does not open with a normal force, the nut can be thawed with a blowtorch.

If the valve will not open readily, the hydrant cap should be removed and inspected for ice by lowering a small weight on a string. If the barrel contains ice, it may be thawed by injection of live steam from a portable steam thawer. Another method of thawing is by pouring hot water into the barrel, using pails or a hose from a nearby hot potable water source. When the ice is thawed enough to permit the valve to open and water to flow, the valve should be opened and flushed slowly until all ice is removed. If the hydrant barrel does not drain, the water should be pumped out and the drain valve (where applicable) checked.

LEAKAGE TESTS

Annually, test the hydrant for tightness of joints and fittings in the following manner.

1. Remove one hydrant cap and replace it with a cap fitted with a pressure gage. Open the valve slowly until it is wide open.

2. Check for leakage at each of the points indicated below.

IN THE TOP OF HYDRANT. If a leak is found, remove the cover and tighten or repack the packing gland.

WHERE NOZZLES ENTER THE BARREL. For leaks here, calk the connection with lead.

NOZZLE CAPS. If the nozzle caps are leaking, replace any defective gaskets.

CRACKS IN THE BARREL. For leaks emanating from cracks in the barrel, install a new barrel or a new hydrant.

DRAIN VALVE (where applicable). This valve should be closed when the hydrant is open. If water comes out of the drain or up around a hydrant, open the hydrant valve and replace the drain-valve facing or gasket.

3. Close the valve, open the second nozzle, open the valve and flush the hydrant.

4. Close the hydrant slowly and note the lowering of the water level in the hydrant after the valve is closed. If the water level does not drop, place your ear against the hydrant. If noise is heard, the main valve probably is leaking and must be replaced. If no noise is heard, the drain valve is plugged and must be opened.

VALVE PARTS

Annually, when the valve leakage tests are made, ensure that the operating nuts, nozzle threads, and chains are carefully inspected.

If an OPERATING NUT is chewed or has rounded corners, remove it and replace with a new nut. Lubricate the nut by removing the screw in the top of the nut and adding the lubricant recommended by the manufacturer. If necessary, lubricate the packing and the thrust collar by oiling the joint between the nut and the collar.

The ease with which the NOZZLE can be screwed off and on should be checked. If the threads are damaged, the nozzle and/or the cap should be replaced.

If the CHAINS are stuck to the caps by excess paint and do not move freely, the paint should be chipped out. Lost chains should be replaced.

VALVE REPAIR

Valve repair is limited primarily to globe valves and gate valves. The other types of valves may be repaired in much the same manner as globe valves, with appropriate modifications as necessary. Valve repair, other than routine packing, is generally limited to overhaul of the seat and disk. However, all other parts of the valve must be inspected, and if found defective, must be repaired or replaced. You should know now to repair a defective valve. However, if the valve cannot be repaired, you must use judgment concerning the salvaging of parts of the defective valve.

SPOTTING-IN VALVES

The method used to determine visually whether or not the seat and the disk make good contact with each other is called spotting-in. To spot-in a valve seat, first apply a thin, even coat of prussian blue (light lubricating oil) over the entire machined face surface of the disk. Then insert the disk into the valve and rotate it a quarter turn, using a light downward pressure. The prussian blue will adhere to the valve seat at points where the disk makes contact.

After you have noted the condition of the seat surface, wipe all the prussian blue off the disk face surface. Apply a thin, even coat of prussian blue to the contact face of the seat, and again place the disk on the valve seat and rotate the disk a quarter of a turn. Examine the resulting blue ring on the valve disk. The ring should be unbroken and of uniform width.

If the blue ring is broken in any way, the disk is not making a proper fit.

GRINDING VALVES

To gind-in a valve, apply a small amount of grinding compound to the face of the disk. Insert the disk into the valve and rotate the disk back and forth about a quarter of a turn, shifting the disk-seat relation through several rotations. During the grinding, compound will gradually be displaced from between the seat and disk surfaces; therefore, it is necessary to stop every minute or so to replenish the compound. When you do this, you should wipe both the seat and the disk clean before applying the new compound to the disk face.

When it appears that the irregularities have been removed, spot-in the disk to the seat, in the manner previously described.

Grinding is also used to follow up all machining work on valve seats or disks. When the valve seat and disk are first spotted-in after they have been machined, the seat contact will be very narrow and will be located close to the bore. Grinding-in, using finer and finer compounds as the work progresses, causes the seat contact to become broader. The contact area should be a perfect ring, covering approximately one-third of the seating surface.

Be careful that you do not over-grind a valve seat or disk. Over-grinding tends to produce a groove in the seating surface of the disk, and also tends to round off the straight, angular surfaces of the disk. Machining is the only means by which over-grinding can be corrected.

LAPPING VALVES

A cast-iron LAPPING TOOL or LAP, of exactly the same size and shape as the valve disk, is used to true the valve seat surface. THE VALVE DISK MUST NEVER BE USED AS A LAP. Lapping allows you to remove slightly larger irregularities from the valve seat than can be removed by grinding. The most important points to remember while using the lapping tool are as follows:

1. Do not bear heavily on the handle of the lap.
2. Do not bear sideways on the handle of the lap.
3. Change the relationship between the lap and the valve seat so that the lap will gradually and slowly rotate around the entire seat circle.
4. Keep a check on the working surface of the lap. If a groove develops, have the lap refaced.
5. Always use clean compound for lapping.
6. Replace the compound often.
7. Spread the compound evenly and lightly.
8. Do not lap more than is necessary to produce a smooth and even seat.
9. Always use a fine grinding compound to finish the lapping job.
10. Upon completion of the lapping job, spot-in and grind-in the disk to the seat.

LAPPING AND GRINDING COMPOUNDS

Only approved abrasives should be used for reconditioning valve seats and disks. The current specification for lapping and grinding compound is listed as SS-L-1682 in FSC 5350. This compound is supplied in six grades, four of which are suitable for lapping and grinding valve disks and seats. The coarse grade is used when extensive corrosion or deep cuts and scratches are found on the disks and seats. The medium grade is used to follow up the coarse grade, and may also be used to start the reconditioning process on valves that are not too severely damaged. The fine grade should be used when the reconditioning process nears completion. The microscopic fine grade is used for finish lapping and for all grinding-in.

REFACING VALVES

Badly scored valve seats or disks have to be refaced either in a lathe or in a reseating machine. Scored, high-pressure steam line valves should be refaced on a lathe because the valve is Stellite-faced.

To reface a composition valve seat (bronze, etc.), attach the correct 45-degree facing cutter to the hand reseating tool. With a fine file, remove all high spots on the surface of the flange (sometimes inside the valve opening) upon which the chuck jaws are to fit. The valve must have the inside of the bonnet flange bored true with the valve seat before the reseating machine can be used. If this condition does not exist, the valve must be reseated in a lathe, and the inside flange bored true.

Before placing the check in the valve opening, open the jaws of the chuck wide enough to rest on the flange of the opening. Now tighten up on the jaws.

Adjust the lock and the machine spindle in the cutting position and start the cutting by turning slowly on the crank. Feed the cutter slowly so that light shavings are taken. After some experience, you will be able to know by the feel whether or not the tool is cutting evenly all around. Remove the chuck to see if enough metal has been removed.

Be sure the seat is perfect, then remove the 45-degree cutter and face off the top part of the seat with a flat cutter. Dress the seat down carefully to the proper dimensions, which are as follows:

1/16 inch wide for valves 1/4 to 1 inch in size

3/32 inch wide for valves 1 1/4 to 2 inches in size

1/8 inch wide for valves 2 1/2 to 4 inches in size

3/16 inch wide for valves 4 1/2 to 6 inches in size

Remachining the disk is a shop job and should be turned over to shop personnel to do.

Following the refacing, the seat and disk should be ground together with an abrasive, such as a grinding compound, powdered emery, or ground glass mixed with oil. Turn the disk back and forth on the seat, occasionally lifting it from the seat and shifting its position slightly. Continue the grinding until a bearing is obtained all around. Test work by referring to the section on "Spotting-in Valves," which was presented earlier in this discussion on valve repair.

VALVE ACCESSORIES

Accessories for valves require maintenance according to the design, function, and character of the accessory. Use the procedures below as a guide to maintaining the following accessories: gear boxes, valve boxes, floor stands, and valve position indicators.

GEAR BOXES

Most large manually operated valves are operated through gears, as are motor-operated valves. These gears are housed in gear boxes.

Monthly or quarterly, lubricate the gearing according to the manufacturer's instructions.

Semiannually, check the gear operation through a complete cycle of opening and closing. Listen for undue noise and observe smoothness of operation of the valve opening, and check for lubricant leakage from flanges. Upon finding any evidence of improper operation, the operator should open the gear box, inspect the gears, and make whatever repairs are necessary.

Annually, inspect the housing for corrosion; clean and paint it as necessary.

VALVE BOXES

All buried valves must have means for the valve key to reach the operating nut. This unit consists of a cast-iron pipe about 6 inches in diameter, with a special yoke at the bottom to rest on the valve bonnet, and a cover at the street level (or ground level, if not in the street). These valve boxes are adjustable in height; some have covers with lock nuts to prevent unauthorized access.

Maintenance of valve boxes should be on the same semiannual basis as the valve maintenance schedule for operation.

Maintenance consists of cleaning out any debris in the box, checking for corrosion, checking the elevation of the top, and checking alignment of the box so that the valve key can be inserted readily. If the valve box has corroded and is no longer serviceable, remove it and replace it with a new unit. If changes in street or ground level have left the valve box too high or too low, adjust the height so that the cover will be at the street or ground level.

FLOOR STANDS

Floor stands, which are located on an operating floor and facilitate operation of a valve at a lower level (as in a filter gallery), come in three designs—rising stem, nonrising stem, and non-rising-stem-indicating. They may be plain or ball-bearing, or gear-operated. Maintenance operations include the following procedures:

Quarterly, lubricate the stem and, on indicator types, lubricate the rising-indicator collar.

Annually, inspect the condition of the floor stand, clean off corrosion, and paint.

VALVE POSITION INDICATORS

Different types of valves have different types of valve-position indicators. Nonrising-stem gate valves may have indicators on the floor stand. Filter plant valves may have indicators on the filter operating table, and butterfly valves, or other valves, used for flow control or throttling, may have electrically controlled indicator units which look like an ammeter. The maintenance care required depends entirely on the design of the indicator unit. For example, post indicators require lubrication at quarterly intervals; and, electric position indicators should be checked for contacts, wiring, and so on, at annual intervals.

WATER CLOSET BOWLS

Moisture on the floor at the base of a water closet bowl usually indicates that the seal or gasket between the closet and its outlet has failed. It may, however, also result from condensation on the tank or piping, or from leakage of the tank, flush valve or piping. When it has been determined that the leakage is from the seal, remove the water closet bowl and install a new seal to prevent damage to the building and the possible entry of sewer gas into the room.

Instructions on removal of the closet bowl are given below. Since there are different methods of flushing, let us assume, for the purpose of our discussion, that flushing is by means of a flush tank which is mounted on the wall behind the closet bowl.

REMOVING CLOSET BOWL

When removal of the closet bowl becomes necessary, always secure the water supply valve for the fixture to be repaired prior to breaking the water service line on the fixture.

A PLATED ELBOW often provides the means by which the closet bowl is connected to the flush tank. This is an advantage because the flush tank, being a separate unit, does not have to be removed in order to remove the bowl. You do have to remove the elbow, however. To do this, unscrew the packing nut at the tank and at the bowl.

If the design of the fixture makes it necessary to remove the flush tank in order to remove the closet bowl, first disconnect the water supply from the tank. This is done by unscrewing the union nut located underneath the tank. Next, flush the tank to empty it; then remove the screws which hold it to the wall. With that done, remove the water in the trap of the closet bowl by bailing or pumping. Unscrew the nuts used to fasten the bowl to the floor. If these nuts are covered by porcelain caps, simply tap the cap lightly with a mallet to remove it. Now give the closet bowl a little jar with the hand and ease it away from the floor.

REPLACING CLOSET BOWL

In replacing the closet bowl, use preformed sealing rings when setting the bowl in place. For satisfactory results, follow the procedure for installing closet bowls as presented in chapter 4 of this training manual.

It is well to remember that if the hold-down bolts or nuts are badly worn or corroded, they should be replaced. Make sure, also, that the floor area where the bowl is to be placed is clean and dry. Tighten the hold-down nuts the amount necessary to have the bowl set level on the floor.

NOTE: In servicing plumbing fixtures, you may often have the job of clearing stoppages in water closets. Information on tools and chemicals used in clearing stoppages in water closets, as well as other fixtures, is given later in this chapter.

FLUSH TANK

You will find it an advantage to know the basic principle on which the flush tank operates. This will help you in locating the source of trouble when a tank gets out of order. Therefore, before we take up the repair phase of the flush tank, let us discuss briefly what goes on inside this mechanism during the process of flushing. For clarity, refer to figure 5-7 as we go along, keeping in mind that in different types of flush tanks you may find some variation in the method of operation.

PRINCIPLE OF OPERATION

When you trip the lever outside the flush tank the rubber STOPPER BALL is raised from the VALVE SEAT to release water into the closet bowl. During this emptying process, the FLOAT BALL moves downward as the water level recedes. Movement of the FLOAT ARM causes a plunger in the INLET VALVE ASSEMBLY to open and a new supply of water is admitted through the SUPPLY PIPE. The stopper ball seats as the water flows from the tank; incoming water helps to hold the ball in position. Hence, the new supply of water is held for the next flushing. As the water level rises during refilling, the FLOAT BALL also rises with it. The buoyance of the float ball provides the force needed to lower the plunger (see figure 5-8) to shut off the water as the tank fills.

In figure 5-7 notice that there is a small REFILL TUBE which feeds into the OVERFLOW PIPE. During the refilling process, water passes through this tube and into the OVERFLOW PIPE, and thence to the closet water trap. The purpose of the refill tube is to ensure replacement of water in the trap. It is essential that this water be replaced as a safeguard to keep sewer gases from coming through the waste pipe.

REPAIRS

When water continues to run into the closet bowl after the flush tank is full, the trouble is in some part of the inlet valve assembly. As

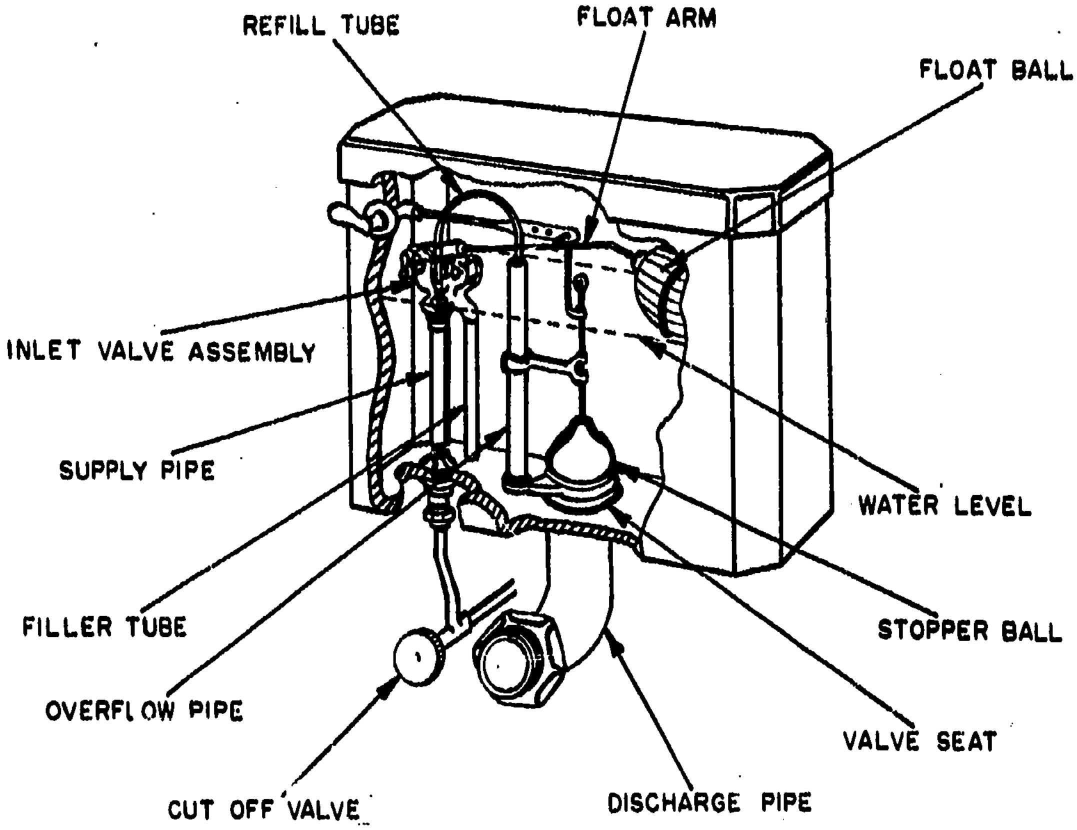


Figure 5-7.—Water closet flush tank. 54.392

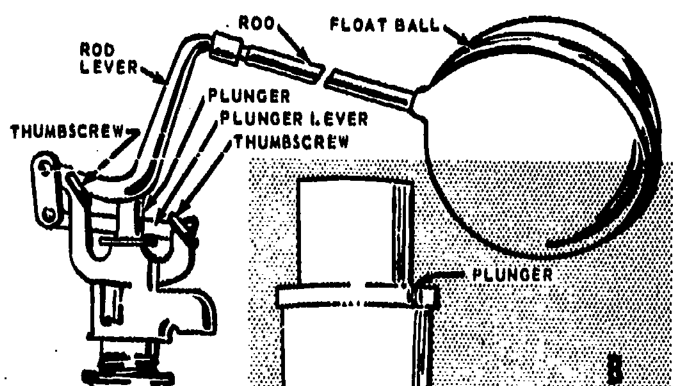


Figure 5-8.—(A) Ball Cock (assembled). (B) Plunger, washer and cap. 54.79

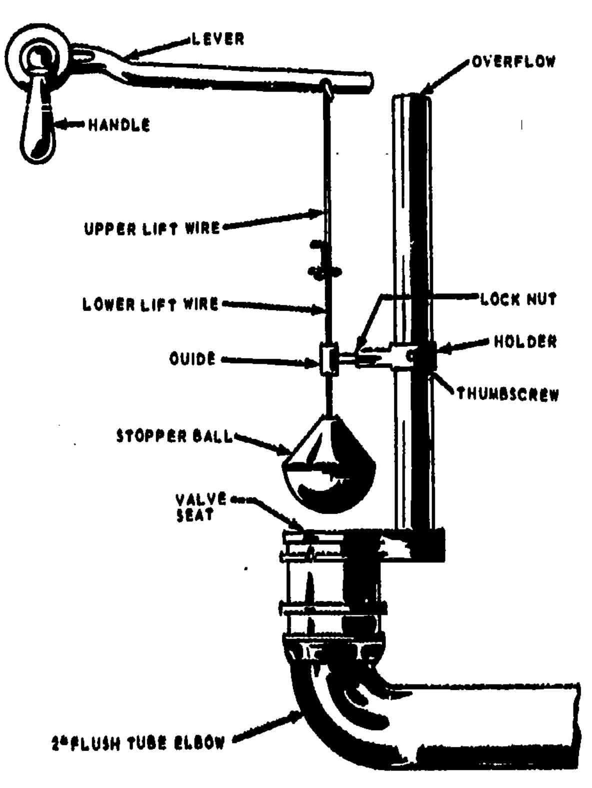
you can see—if you understand the details of operation given above—the plunger has failed to close the inlet valve as it should, and thus the excess water which continues to flow in (after the tank has reached the proper level) is being discharged through the overflow pipe and into the bowl. In checking for the source of trouble, here are the defects to look for: a leak in the float ball, a bent float arm, a worn washer on the bottom of the plunger, or a worn valve seat.

A good place to start is with the float ball, keeping in mind that a leaky, water-logged float will prevent the plunger from closing properly. A small leak in a copper float can be remedied by soldering. If it is a large leak, though, simply replace the float with a new one. A damaged float arm should also be replaced with a new one. Sometimes you may find that the float arm is only bent or not allowing the valve to close far enough. In this case, the remedy is to bend the float end downward a bit, the purpose being to push the valve tighter into its seat.

When necessary to replace the washer on the bottom of the plunger (see part B, figure 5-8), start by shutting off the water. Then unscrew the two thumbscrews that pivot the floatrod lever and the plunger lever (see part A, figure 5-8). Push the two levers to the left, drawing the plunger lever through the head of the plunger. Now lift out the plunger, unscrew the cap on the bottom, insert the new washer, and reassemble the parts. If the cap is badly corroded, replace it with a new one. In replacing the washer, examine the seat for nicks and grit, which, if present, may necessitate regrinding.

To consider another common disorder, suppose that water continues to run into the closet bowl after flushing, yet the tank does not refill. This indicates that some part of the FLUSH VALVE assembly is at fault, the result being that the flush valve is not closing properly. To locate the trouble and get the tank back in proper working order, proceed as follows:

First, stop the inflow to the tank by holding up the float ball or supporting it with a stick. Then drain the tank by raising the rubber stopper ball. (See fig. 5-9.) Now examine the stopper ball to see if it is worn, out of shape, or has lost its elasticity. If either condition exists, unscrew the lower lift wire from the ball and replace the ball with a new one. See that the lift wire is easily fitted over the center of the valve by means of the adjustable guide holder. By loosening the thumbscrew you can raise, lower, or rotate the holder, about the overflow tube (see fig. 5-9). The horizontal position of the guide is fixed exactly over the center of the valve by loosening the locknut and turning the guide screw.



54.80
Figure 5-9. — Flush valve for low tank.

The upper lift wire should loop into the lever armhole nearest to a vertical from the center of the valve. A tank should empty within 10 seconds. Due to lengthening of the rubber ball and insufficient rise from its seat, the time may be longer than 10 seconds and the flush correspondingly weak. This may be overcome by shortening the loop in the upper lift wire. A drop or two of lubricating oil on the lever mechanism makes it work more smoothly.

FLUSH VALVES

There are two major difficulties that may occur in connection with flush valves: (1) The valve may run continuously, instead of shutting off at the right time, or (2) the valve may fail to deliver the desired amount of water (short flushing). Both of these defects can result in the waste of a great amount of water over any considerable period. Since it is to avoid waste that flush valves are installed, their proper maintenance is an important factor. Once you understand the principle and the operation of a valve, you will know what to look for when anything goes wrong. A flush valve normally should give years of adequate and trouble-free operation if it is properly maintained.

Continuous flow through a piston-type flush valve is almost always caused either by failure of the relief valve to set properly, or by corrosion of the bypass valve. In both these cases, there is not enough force on the piston to force it to seat.

If the relief valve fails to seat as it should, the leakage that occurs may be sufficient to prevent the upper chamber of the valve from filling, and the piston will therefore remain in the open position. Inspect the relief valve seat for dirt or other foreign substances that may be causing the relief valve to tilt; disassemble the piston, wash the parts thoroughly, and reassemble. Replace worn-out washers, making sure that the surface upon which the washer sets is perfectly clean; scrape off old rubber, if any adheres to the metal surface.

Corrosion of the bypass valve in the center of the top plate will also cause continuous flow; the water is unable to pass into the upper chamber of the valve, and there is no force exerted on the piston, to move it downward to its seat. Very dirty water passing through the system can clog the bypass, and deprive the upper chamber of water. If pipelines in a new installation are not thoroughly flushed out before they are placed in operation, the pipe dope or dirt accumulated in them can stop up the bypass valve.

The same condition can arise in a diaphragm valve. If chips or dirt carried by the water lodge between the relief valve and disk, the relief valve will not seat securely, and the leakage that occurs will prevent the upper chamber of the valve from filling with water. The valve will then remain in the open position, since there will be no pressure to force the diaphragm to its seat.

Short flushing can occur in a diaphragm type valve. If the disk, diaphragm, and guide have not been assembled tight, you may have to reassemble the valve in order to get proper operation. Sometimes you may find that someone has tampered with the bypass tube, enlarging it to such an extent that the water passes so rapidly into the upper chamber that it closes off the valve before the desired volume has been delivered. It may be, too, that someone has oiled or greased the valve parts, in the mistaken idea that this would make the valve operate more easily. What really happens is that the oil or grease swells and ruins the rubber parts, thus interfering with the action of the valve.

FAUCETS

You may recall from chapter 4 that a number of different types of faucets are used in plumbing installations. With space being limited, we are primarily interested here in repairs to the compression-type of faucet. If you can make repairs on this type, you should have little trouble repairing other types of faucets. A cutaway view of a compression faucet is shown in figure 5-10. This type of faucet, with disk washer and solid or removable seat, requires frequent attention to maintain tight closure against water pressure.

When a faucet is turned on or off, the washer on the end of the stem rubs against the seat. This rubbing wears down the washer and eventually causes the faucet to drip. Even a small, steady leak in a faucet, if ignored for long, can waste an enormous amount of water. From the standpoint of economy, therefore, a faucet suffering from "driposis" should be fixed promptly. Frequently, the remedy for a dripping faucet is to replace the washer.

To replace the disk washer on a compression faucet, first shut off the water supply to the

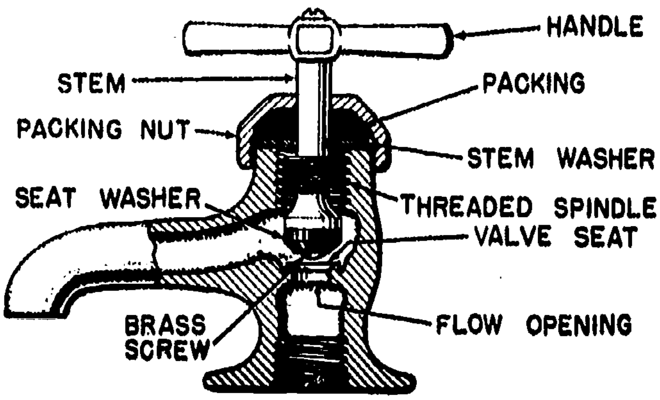


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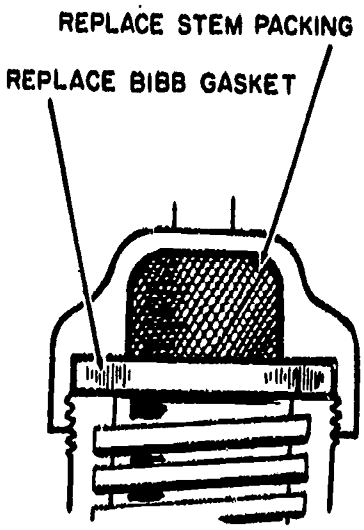
Figure 5-10. —Compression faucet.

faucet and open the faucet all the way. Then remove the faucet handle, bonnet, and stem. Next, remove the brass screw holding the washer to the bottom of the spindle. Replace the washer with a new one which is flat on one side and slightly rounded on the other so it can get both horizontal and vertical pressure and provide a firm seat. Use a good quality hard-composition washer because leather or soft washers do not give long service, particularly in hot water lines. If the brass screw is in poor condition, replace it with a new one.

Examine the valve seat and repair or replace it with a new one, if necessary, before replacing the spindle. If this is not done, a new washer may provide adequate service for only a short time. Reface or ream solid-type seats with a standard reseating tool consisting of a cutter, stem, and handle. Rotate the tool with the cutter



54.211
Figure 5-11. --Stopping leak at bonnet.

centered and held firmly on the worn or scored seat. Take care to prevent over-reaming. Remove all grindings prior to reassembly. Solid-type seats can be replaced with renewable-type seats by tapping a standard thread into the old solid seat and inserting a renewable-type seat. Remove renewable seats with a regular seat-removing tool or Allen wrench. When the seat is frozen to the body, apply a little kerosene to loosen it. Tapping, reseating, or replacing of faucet seats can, in most cases, be accomplished without removing the faucet from its fixture.

To stop leakage at the bonnet, replace the stem packing the bibb gasket (see fig. 5-11).

You may find ball-bearing type washer holders installed in faucets at some activities. The ball bearings, between the stem and washer holder, permit movement of the "washer" independent of the movement of the stem. This allows the washer to stop its rotation on the slightest contact with the seat, thereby reducing the frictional wear of the washer.

SHOWER HEADS

Shower heads that supply an uneven or distorted stream can usually be repaired by removing the perforated face plate and cleaning the mineral deposits from the back of the plate with fine sandpaper or steel wool. Free clogged holes with a coarse needle or by "blasting" with compressed air.

INSULATION AND HANGERS

When insulation is properly installed, it should remain in good condition for a long time. However, accidents such as broken hangers, and leaking valves do occur. When it becomes necessary to repair a section of defective insulation, it may only be necessary to re-cover the insulation with waterproof paper or canvas; this will depend, of course, upon the situation. Anyhow, before doing any repair work to the insulation, try and determine the cause of failure; then take the necessary action to correct the basic source of trouble. What happens, in some instances, is that a hanger comes unfastened or breaks, thus causing the pipe to sag and break or to crack. In such a case, repair or replace the pipe hanger, as the case demands. Then repair (or replace) the pipe or fitting and reinstall the insulation. Follow the instructions presented in chapter 4 of this manual regarding the selection and installation of insulation.

SEWER MAINTENANCE AND REPAIR

In working with sewers, most of the troubles that you encounter will be in the form of stoppages and breaks. Stoppages will probably be your most common source of troubles. A common cause of stoppage in a sewer system is tree roots. Other causes include sand, gravel, and greasy or tarry materials. When sand, gravel, or just plain mud is noted in quantities, this indicates a broken or loose sewer joint or pipe.

It should be noted that explosions in sewers are not uncommon and should be guarded against. Check with your local safety office for the most current regulations and information concerning this.

Systematic inspection and maintenance permits early correction of faults before major defects and failures develop. Trouble calls will be received occasionally, however, concerning stoppages or slow drainage. The first step in correcting the trouble is to determine the cause.

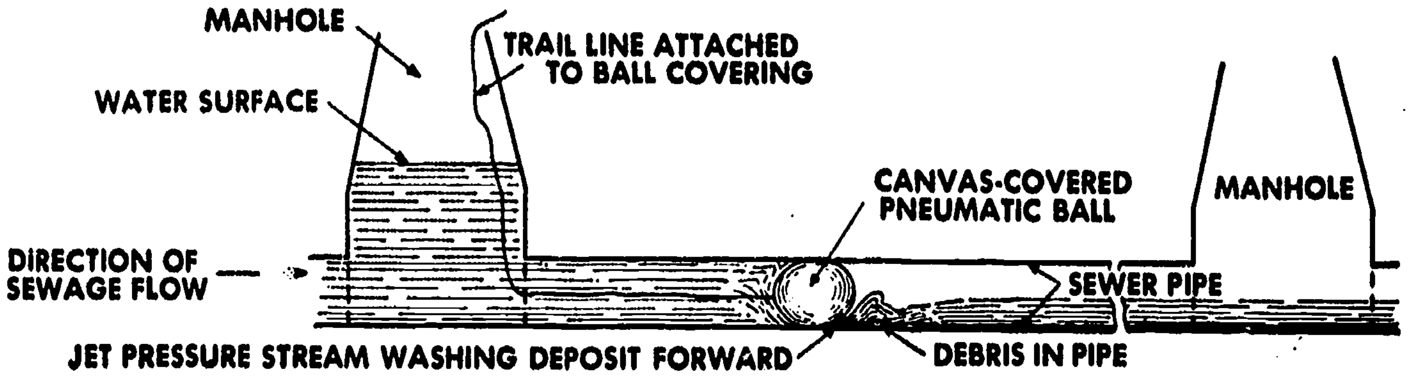
Inspection of a sewerline can be done from manhole to manhole by men using a flashlight or a reflecting mirror—or both. One man acting as an observer can look up the sewerline towards the flashlight which is held by a second man in the preceding manhole. The condition of the line can be noted in this manner to determine if cleaning of roots or other obstructions is feasible.

Routine sewer maintenance includes flushing, cleaning, and immediate repair to defective sewers. Information that will aid you in flushing, cleaning and repairing sewers is given below.

FLUSHING

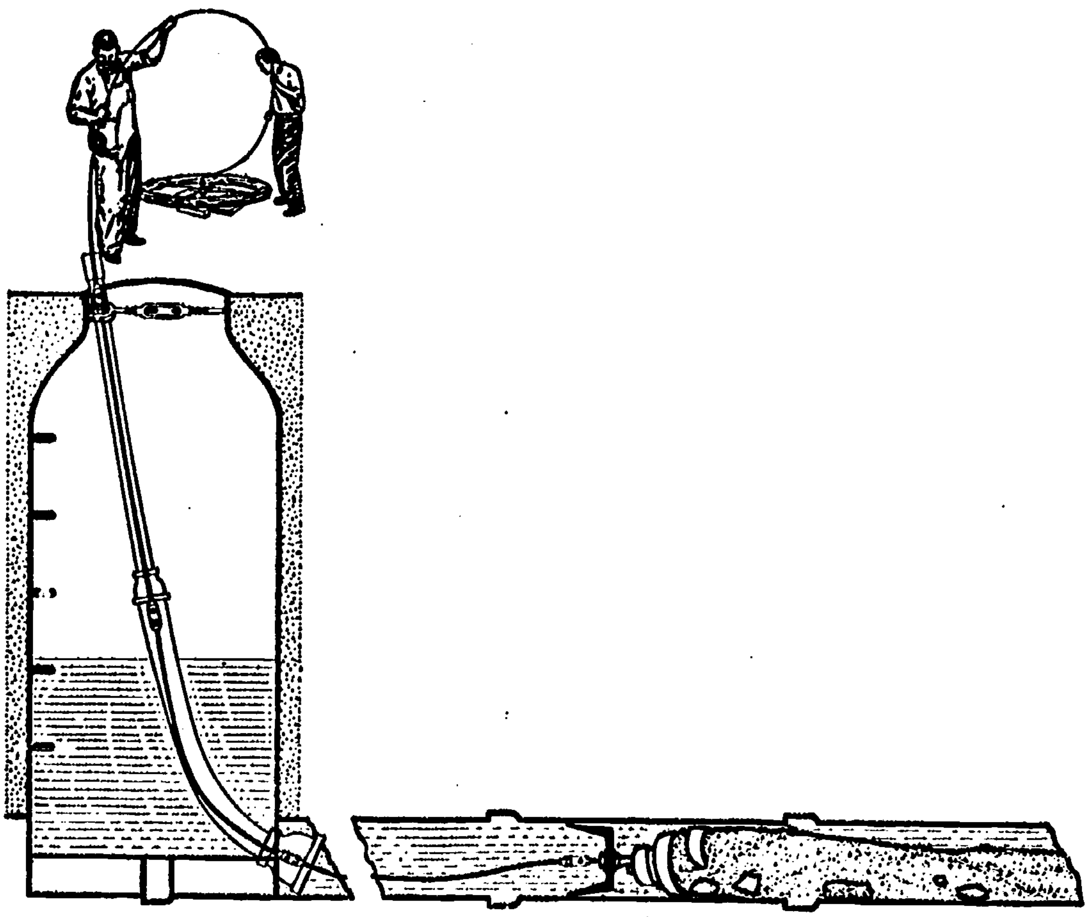
Flushing aids in the removal of loose organic solids and sand or grit deposits from sewers. Flushing is not an efficient method of sewer cleaning unless a high velocity can be maintained between manholes on a short run; in other words, you depend on the high velocity for the complete scouring action on the sewer. Flushing may be accomplished by a number of methods, two of which are by use of a fire hose and by the pneumatic-ball method.

When flushing is to be done by use of a fire hose, you will need enough fire hose to reach between manholes. In using this method, first string a rope or light cable through the sewer with sewer rods if a plain fire nozzle is used, starting at the upper end of the system, and draw the flowing nozzle through the sewer. If a self-propelling turbine-type nozzle is used, the



87.24

Figure 5-12. — Ball method of sewer flushing.



54.393

Figure 5-13. — Sand cup and auger used with flexible-steel rods.

rope is not required. Use 2 1/2-inch fire hose discarded by the fire department if possible. Paint the sewer-flushing hose at the ends with an identifying color to prevent use for emergency potable-water connections.

In using the pneumatic-ball method of flushing, inflate a light rubber ball, such as a beach-ball or volley-ball bladder, to fit snugly in the sewer, and place it in a small canvas or burlap bag with a light rope attached. Place the ball in the sewer, hold the line until the sewage backs up in the manhole, and allow the ball to move to the next manhole. When an obstruction is reached, the pressure presses the ball against the crown of the sewer, causing a jet at the bottom. (See fig. 5-12.) As much as 4 miles of sewer can be cleaned in 8 hours by this method, which works for sewers up to 30 inches in diameter. A wooden ball with a diameter 1 inch less than the sewer may also be used. Where sewage flow is low, addition of water to the upper manhole may be required.

In the sand cup method, a sand cup with auger is attached to flexible-steel sewer rods and run through the sewer (see fig. 5-13). The rubber cup is perforated to provide flushing action.

CLEANING

In routine sewer cleaning, the usual operation is to put a tool through the line which will either indicate a clean sewer, remove partial obstructions, or determine the necessity for a detailed job, such as grease removal, root cutting, or sand removal.

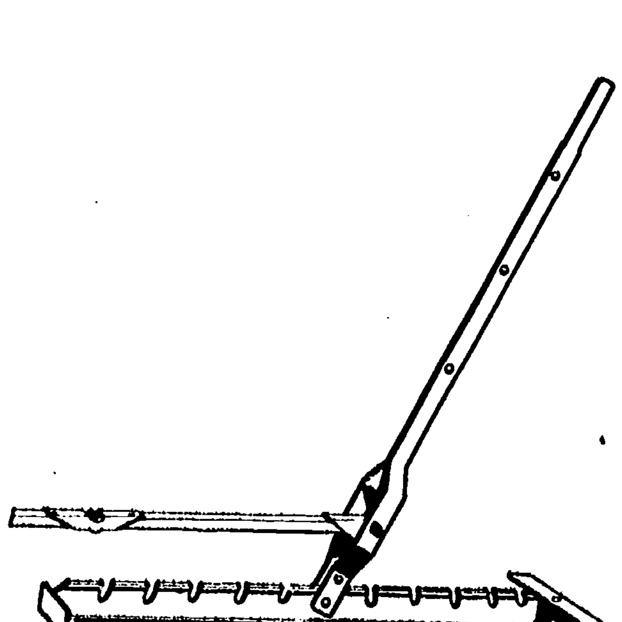


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Figure 5-14. — Pushing device for wood sewer rods.

Sectional wooden sewer rods, to which a variety of end tools may be attached, have been used in sewer cleaning for many years. End tools for initial piercing of an obstruction, and cutters and scrapers for root and grease removal, are available. Rods are pushed into the sewer from the bottom of a manhole. A device such as that shown in figure 5-14 is useful for pushing the rods. Wooden rods are particularly useful to string a cable through a partially obstructed sewer.

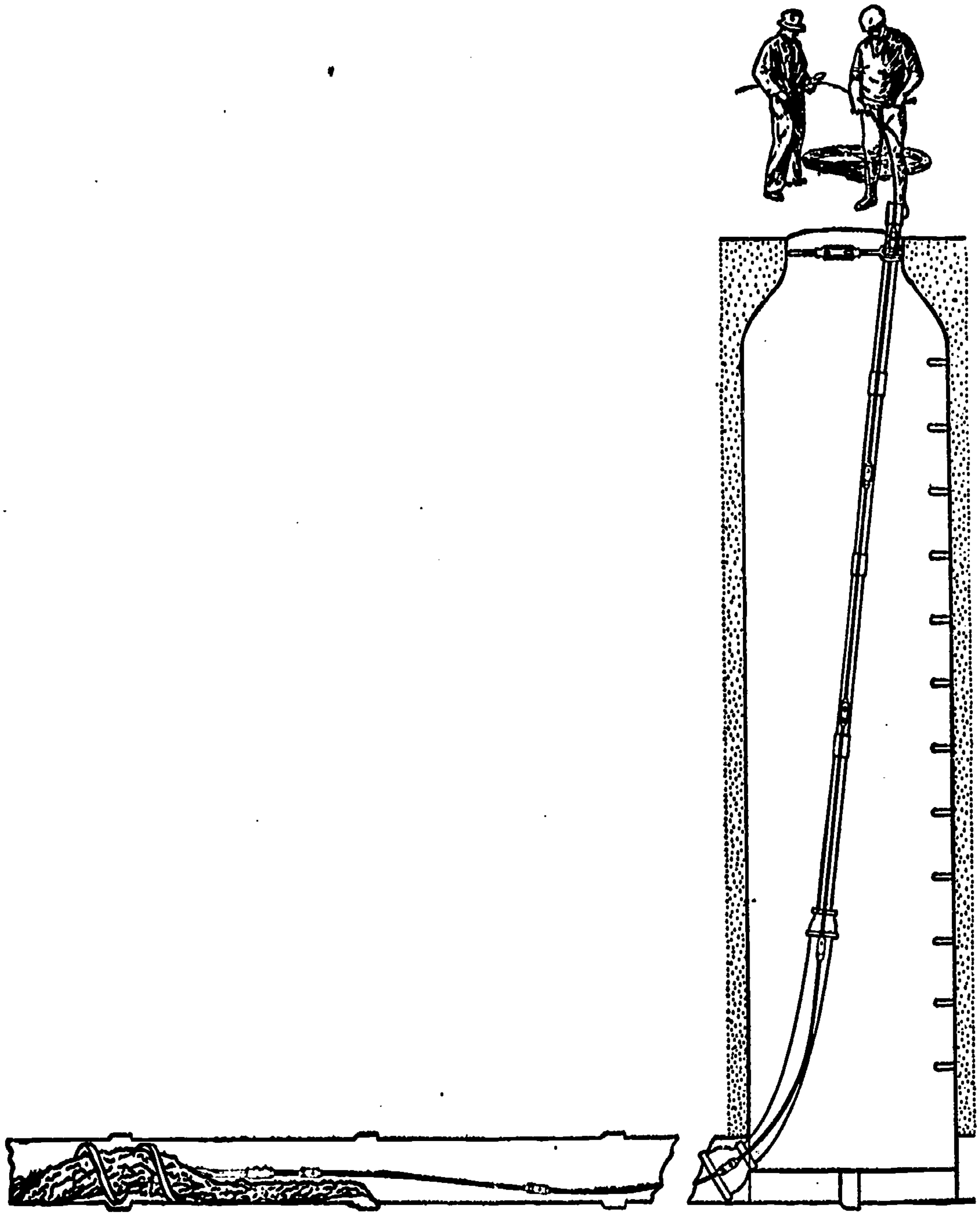
Another method of sewer cleaning involves the use of light-weight, spring-steel sectional rods coupled into a continuous line, with several types of augers and sand cups used as end tools. (See fig. 5-15.) The tool and rod are fed into the sewer until the obstruction is reached; then the obstruction is removed by twisting the rod by hand or by use of a small gasoline-engine drive. NOTE: Where power-driven equipment is used, ensure that it is maintained in accordance with the manufacturer's recommendations.

Flushing methods described in the previous section remove all but heavy sand deposits. Accumulated sand and grit dislocated by flushing should be removed from the sewer at a manhole. A sand trap, made from stove-pipe ell and sheet metal to fit the sewer pipe, may be used, as shown in figure 5-16, to collect the sand. Commercial traps are available with adjustable slots to lower the water level below the top of the trap. Sand is removed by scoops or buckets.

For heavy sand deposits, a cable-drawn bucket is used, especially for storm sewers and larger sanitary sewers. The cable may be pulled by hand winch, power winch, or by a truck with the cable through an anchored sheave. Damage to the sewer may occur if the bucket catches on misaligned joints, improper house connections, or other fixed obstructions. This is especially true for power-driven buckets.

Turbine cleaning tools (see fig. 5-17) are useful in sewer cleaning where difficult obstructions and grease coatings exist. These tools are powered by water under pressure from a fire hose. The tool and hose are pulled through the sewer by cable.

Various types of power-driven sewer cleaning machines are available. In your work the type used may be the same or similar to that shown in



54.395

Figure 5-15.—Root removal by steel rod and auger, manual operation.

figure 5-18. This machine has a $\frac{3}{4}$ HP electrically reversible motor and weighs approximately 90 pounds. It is especially designed for clearing sewer pipelines ranging from $1\frac{1}{2}$" to 10" in diameter and up to 200 ft. in length. It has a cable counter indicator so that the operator will know the distance the tool is in the line. It also has a headlight which will aid you in working in dark areas.

A major difficulty encountered with sewer systems buried in the ground is tree ROOTS. These are hard to detect just by looking in the manholes. With trees growing rather close to a sewerline, you often can expect roots to cause a break in the line. Such trees as poplars, willows, and elms are the most troublesome when it comes to root growth. When these trees are growing within 100 feet of a line, you can

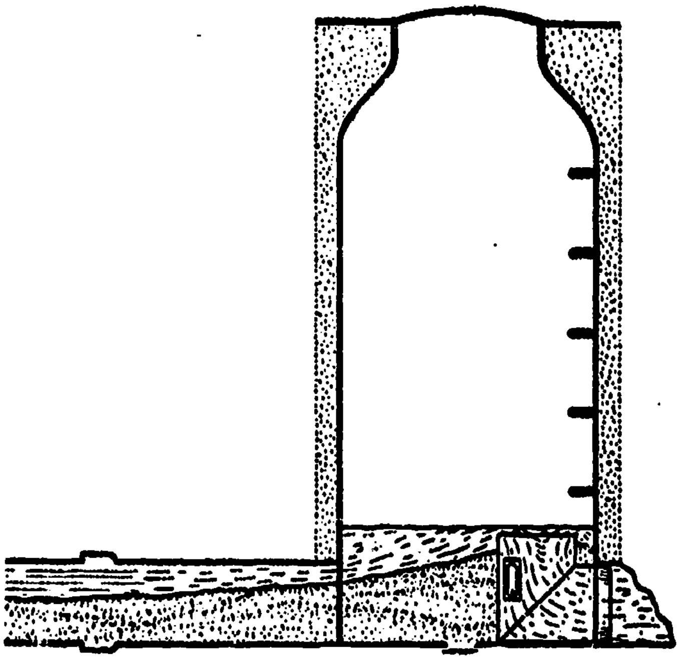


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Figure 5-16. —Sand trap.

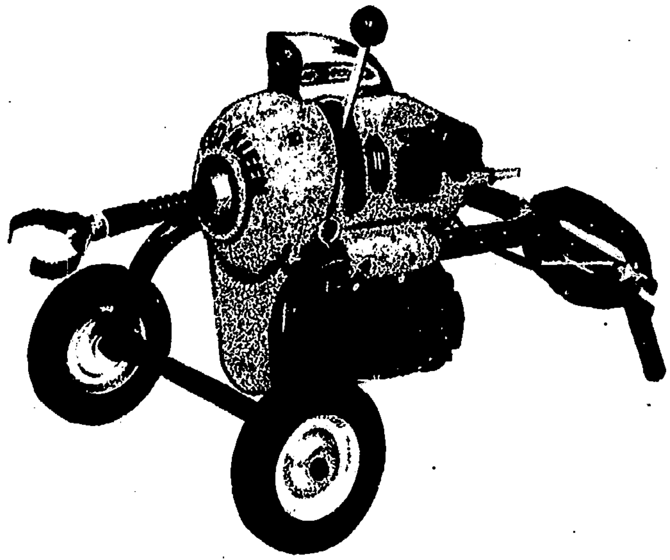

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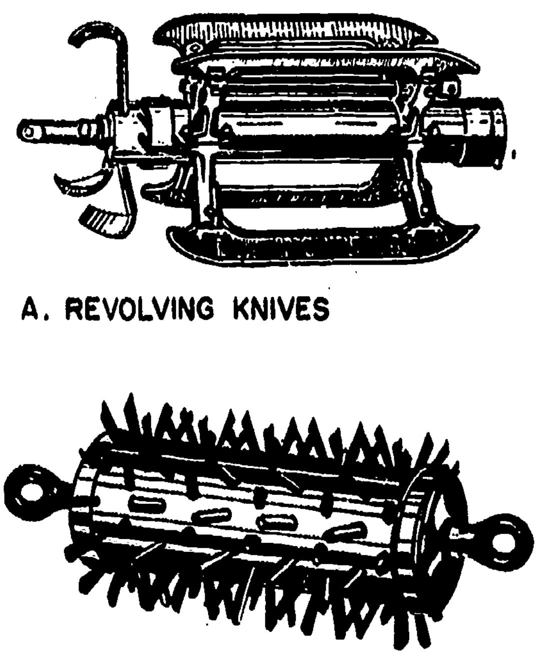
Figure 5-18. —A power driven sewer cleaning machine.



54.397
Figure 5-17. — Turbine-driven tools.

look for trouble from roots to occur — sooner or later. Take a close look at figure 5-19, which shows how tree roots actually penetrate a line.

One method used in the removal of tree roots in sewers is the application of copper sulfate (blue vitriol). Another method is by use of cable-drawn scrapers, which may be of home-made construction (see fig. 5-20). The application of copper sulfate should be attempted first, since this is the most economical procedure.

Stoppage can be detected by the nature of the flow of sewage and also by the conditions in the bottom of the manhole. Where stoppage is due to roots, sewage will back up into the next manhole above during periods of greatest

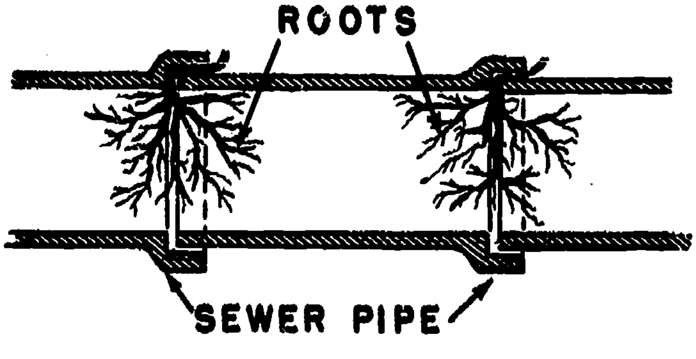


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Figure 5-19. —Roots growing into sewer pipe.

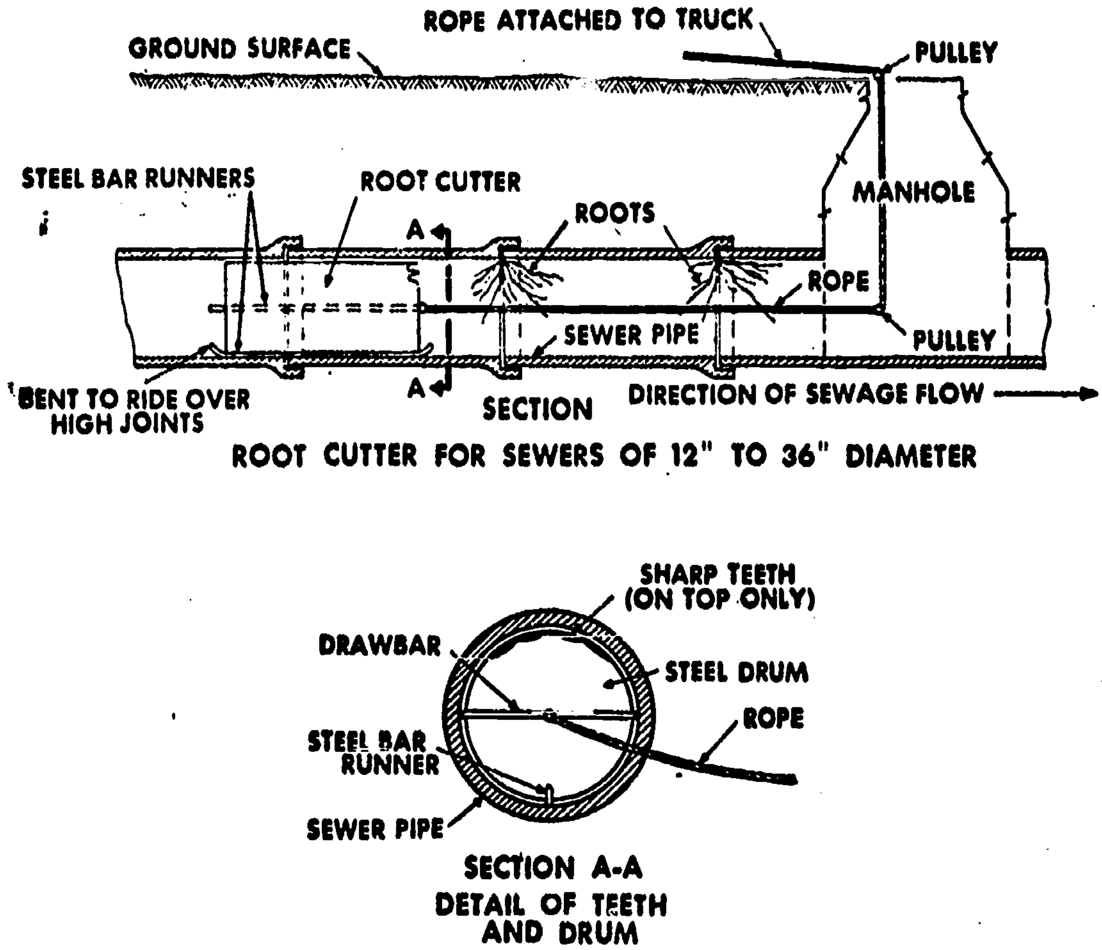

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Figure 5-20. —Homemade scraping and root-cutting tools, cable-drawn.

flow during the day, and will recede during periods of low flow. This condition may exist for days or possibly weeks before the sewage begins to overflow the top of the manhole and run into the street. By throwing in the copper sulfate crystals while the sewage is still flowing, a sufficient concentration of the poison will usually reach the seat of the trouble to eliminate it before the stoppage is complete. It is important to remember that it is useless to apply the copper sulfate in the sewer that is completely stopped, for unless there is at least a small flow of sewage through the obstruction there is no chance for contact between the roots and the copper sulfate solution. Sewer rods would be the only remedy to start some flow through and allow the copper sulfate to reach the roots. Since it is only necessary to kill the small root which enters the sewer and not the great mass of roots branching from it, the important factor is in reaching the feeder root with the killing chemical. The flow pulling on the large heavy brush causes the weakened base root to break. There is no set rule as to the exact quantity of crystals required for good results. However, the ideal condition seems to be where a small flow of sewage, say from 5 to 10 gallons per minute, is trickling through the mass of roots. In cases like these, a handful of the crystals applied in the manhole directly upstream from the stoppage will relieve the obstruction. If the flow is greater, as determined from looking in the manhole just below on the downstream side of the stoppage, greater quantities and possibly repeated applications would be necessary. It is the time of contact of the chemical with the roots that is important rather than the amount of chemical. If copper sulfate fails to remove tree roots, then use power-driven or cable-drawn scraping and cutting tools.

REPAIR

Make it a practice to see that sewer breaks, severe obstructions, and other conditions causing sanitary hazards are repaired at once. The cause of trouble should be determined where possible, and repairs made to prevent recurrence of the difficulty. Thus, substantial bedding must be provided in replacing misaligned sewers, and backfill must be carefully placed and tamped. Leaking joints are preferably recalked with a bituminous joint compound. Sewers beneath roads or railroads that are crushed by settling must be encased in concrete or replaced with cast-iron pipe unless the soil has become stabilized. In difficult situations, technical assistance of higher authority should be obtained.

Bypassing the sewage flow is usually required during repairs. The usual method is blocking the upper manhole outlet with sand bags or an expandable rubber plug, using portable pumps to discharge the sewage to the lower manhole through a fire hose or a temporary pipeline.

Excavations must be braced and ladders provided in accordance with safety requirements for excavation, building, and construction. Adequate guards and warning signs must be placed around the excavations in roadways.

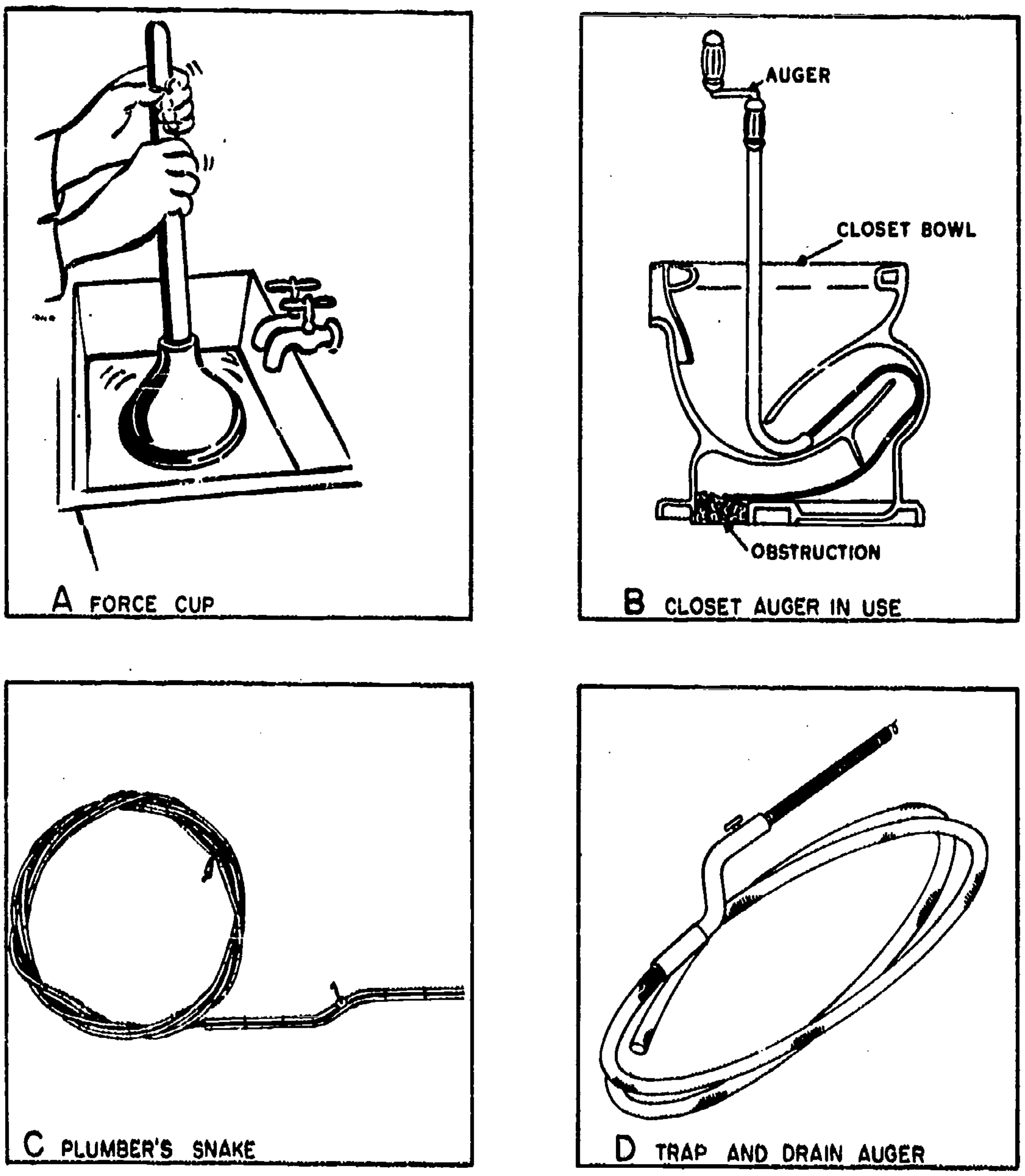

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Figure 5-21. — Tools for clearing stoppages in plumbing fixtures.

CLEARING STOPPAGES IN FIXTURES

Stoppages in fixtures are usually caused by improper materials lodging in the drain, trap, or waste line. Obstructions often can be removed by manually operated devices, by chemicals, or, when necessary, by combinations of both. The method depends upon the seriousness and nature of the stoppage. The obstruction should be entirely removed and not merely moved from one place to another in the line. After the stoppage has been relieved, pour boiling water into the fixture to ensure complete clearance. Some of the methods used in clearing stoppages in fixtures are explained below.

The FORCE CUP, frequently referred to as the PLUMBER'S FRIEND, is commonly used for clearing stoppages in service sinks, lavatories, bathtubs, and water closets. One type of force cup has a round rubber suction cup, about 5 inches in diameter, fastened to a wooden handle. (See view A, fig. 5-21.) In using the force cup, partly fill the fixture with water. Then place the force cup over the drain opening and work the handle up and down to provide alternate compression and suction actions. The downward pressure or upward suction often clears the stoppage. Another type of force cup shaped to fit the opening in a water closet drain works more efficiently than the round type in clearing stoppages in water closets.

The CLOSET AUGER and PLUMBER'S SNAKE are used for opening clogged water-closet traps, drains, and long sections of waste lines. (See views B and C, fig. 5-21.) The closet auger is a cane-shaped tube with a coiled spring "snake" inside. It is equipped with a handle for rotating the coiled hook on the end of the snake. To insert the closet auger into the trap of the water closet, first retract the coiled spring all the way up into the cane-like curve of the closet auger. Hook the cane end, with its projecting hook, into the trap. Then start turning the handle, to rotate the coiled spring, as it is pushed down into the trap of the water closet. Rotate the handle continuously until the snake reaches the obstruction in the drain. Turn the handle slowly until the obstruction is caught on the coiled hook of the closet auger. Continue rotating the handle and pull back at the same time to bring the obstruction up into the water closet where it can be removed. NEVER assume that the water closet is clear after one object is brought up and removed. Insert the snake of the closet auger a second time and repeat the procedure until the closet auger will pass down into the closet bend and branch. Withdraw the closet auger. Put 4 or 5 pieces of toilet paper in the water closet and flush them through the fixture to make sure that it is completely open.

TRAP AND DRAIN AUGERS such as the one shown in view D of figure 5-21 are used in clearing obstructions in traps and waste pipes. Trap and drain augers, also known as SINK SNAKES, are made of coiled tempered wire in various lengths and diameters. They are very flexible and easily follow bends in traps and waste lines when pushed into them.

In clearing stoppages from lavatories, service sinks, and bathtubs, first use a plumber's force cup. If the obstruction is in the trap and is not cleared by the action of the plunger, clear the trap by inserting a wire or snake through the cleanout plug at the bottom of the trap. If the trap is not fitted with such a plug, remove the trap. Protect the finish of the packing nut with adhesive tape or wrap a cloth around the jaws of the wrench. Do not use a heavy steel spring coil snake to clear traps under lavatories, sinks, or bathtubs. Use a flexible type of wire or spring snake which will easily follow the bends in the trap. An example of the use of a spring snake is in clearing stoppages from floor drains. Remove the strainer or grate and work through the drain, or insert the snake through the cleanout plug opening nearest to the obstruction.

Bear in mind that stoppage clearance tools should be used with caution. One reason why safety is so important is that a caustic chemical may have been poured into the stopped-up fixture in an effort to clear it. Such caustic agents may cause serious injury if splashed into the face by careless use of the force cup or may burn the hands when the sink snake is used.

If manually operated devices fail to clear stoppages, several types of chemicals can be used to dissolve or burn them out. These are discussed briefly below.

CAUSTIC POTASH (POTASSIUM HYDROXIDE). Stoppages can be burned out by pouring a strong solution of this chemical and hot water into the line through the fixture opening. Pour the mixture slowly into the pipe through a funnel. Since this solution can cause serious burns, personnel must wear goggles and rubber gloves. It will also damage glazed earthen-ware, porcelain, and porcelain-enameled surfaces.

CAUSTIC SODA (SODIUM HYDROXIDE). Kitchen and scullery sink stoppages often present special problems because of grease, oil, or fat washed down along with coffee grounds and small bits of garbage into the drain. Grease congeals and acts as binder for solid particles and can usually be cleared by successive applications of a chemical cleaner. Effective cleaners include sodium hydroxide (caustic soda) with bauxite (an aluminum compound or ore) and other ingredients to intensify their action, or sodium hydroxide mixed with sodium nitrate and aluminum turnings. Adding water evolves ammonia gas, which assists in conversion of grease to soap. This forms a gas, which causes a boiling and heating action and further assists in dissolving the grease. In clearing a partially blocked drain, a small quantity of cleaner (from 2 to 8 ounces) is dropped into the open drain and followed by a quantity of scalding hot water. Such cleaning agents cannot, however, be satisfactorily used when the drain is completely plugged, since some flow is required to loosen the chemicals. A completely blocked drain must first be partially cleared with a plumber's snake before using the chemical cleaner.

SAFETY

Careful attention should be given to SAFETY if accidents are to be prevented on inside or outside plumbing jobs. As a UT 3 & 2 consider it an important function of your job to see that safety precautions are observed at all times. Some of the main safety precautions involving various phases of plumbing are given below. Bear in mind, however, that this training manual does not attempt to tell you all you need to know about safety. The reader is encouraged to make a continuing effort to acquire additional knowledge on the subject of safety through further study and on-the-job experience.

WORK ON PIPING

When acids are used in working on piping, see that they are kept in only glass or lead containers. Exercise care to keep out from under hot joints while they are being poured. Ensure that hot lead is not poured over water or wet calking.

If floors are oily and cannot be kept dry, they should be covered with sand or oil-absorbent compound.

Any tee, valve, or other service connection which is to be used on piping in maintenance or repair operations should be very carefully checked to make sure that it is designed to withstand the maximum pressure that might be exerted on it.

SEWER WORK

Before plumbing work is started on sewer jobs, pits, or tanks where the hazard of broken or leaking pipes may be present, these two preparatory steps must be taken:

1. Gas detectors, respirators, inhalators, standard gas masks, safety belts, lifelines, and blowers must be provided as needed.
2. Tests must be made for explosive gas-air mixtures and oxygen deficiencies in these locations before personnel enter them.

Where such hazards are found to exist, adequate control measures should be instituted and workmen should don suitable respiratory equipment as necessary, before entering the structure. Workmen should be instructed as to the kind of respirator to use in an emergency, and how to assemble and use this equipment properly.

At least two men should be assigned to each sewer job where the hazard of broken or leaking pipes may be present. One man should always be in a relatively safe position and prepared to render assistance in an emergency.

To help dissipate any toxic or flammable gas that may exist in a sewer or underground sewage pumping plant, the manhole cover should be removed several minutes before a workman descends. Additional precautions relating to sewer work are given in chapter 12 of this manual.

PROTECTIVE CLOTHING AND EQUIPMENT

Goggles, gloves, and other protective clothing provided for personnel safety must be worn in all pipe fitting, pipe handling, and plumbing work involving the pouring or handling of hot metal or acid, and in any other work where flying material might injure the eyes. Goggles must be worn when using compressed air to clean out sand, dirt, or scale from pipes before installation.

Flameproof garments must be worn when using blowtorches, welding torches, or similar tools. Plumbers should wear heavy coveralls and leggings which also cover the instep, as a protection against hot lead; if not available, the regular working uniform may be acceptable.

When entering deep tanks, deep sewers, and other deep underground structures, a safety belt and lifeline must be worn.

Portable blowers are recommended for all tank, pit, or manhole work where there is any question as to the presence of noxious gases, vapors, or oxygen deficiency. These blowers should have vapor-proof, totally enclosed motors or nonsparking gas engines, and when used they should be placed not less than 6 feet away from the opening and on the leeward side protected from wind, so that they will not serve as a source of ignition for any flammable gas which might be present.

TOOLS

The following precautions apply to tools in general. (Since pipe wrenches are one of the plumber's most important tools, precautions applicable to this particular tool are given in the following section.)

Tools and appliances should be kept in good condition. Worn tools should be replaced. Check hammer handles frequently; hammers with broken or cracked handles should not be used.

Tools or materials should not be allowed to clutter up the floor and become stumbling hazards. Pieces of scrap pipe should be picked up promptly and taken to the scrap bin or to the scrap tubs for the next scheduled pickup.

Vise jaws should grip the material securely. When threads are being cut, and during backing off operations, the stock should be held firmly.

Freshly cut threads should be protected with caps or couplings when possible. Care should be exercised to guard against sharp burrs or fins.

When operating a pipethreading machine, the clearance of the pipe should always be ascertained before starting the machine.

A cold ladle or other cold material should NEVER be dropped into a pot of molten lead, as an explosion may result.

PIPE WRENCHES

An extension should never be used on a pipe wrench, as it puts a strain on the wrench which it is not designed to take.

Care should be taken to assure that there is plenty of clearance in case the wrench should slip.

An adjustable pipe wrench should always be faced forward in the direction the handle is to turn. When used that way adjustable wrenches can withstand the greatest force, because the pulling force is applied to the stationary jaw side of the handle.

The bite of an adjustable wrench should always be taken near the middle of the jaws, so that there will be teeth in front if the wrench slips.

Small wrenches should not be overstrained. Wrenches should not be subjected to a severe side strain, and they should never be used as hammers.

HANDLING PIPE

Workers should wear leather or leather-faced gloves when handling pipe. They should also stand to one side when pipe is being unloaded from a truck or railway car.

Pipe should be piled so that the ends of the pipe will be even and not project into walkways. It should be stacked straight, that is, not crossed. Pipe should not be piled directly on the bare ground; racks or dunnage should be provided.

Pipe should always be blocked to prevent it from rolling. Where practical, pipe should be stored on specially designed racks.

When lifting heavy pieces of pipe, bend the knees, keep the back line as nearly vertical as possible, and hold the load close to the body; then straighten the knees and pull the load up directly over the feet. Lift with the legs, not with the back.

Pipe should be carried with the forward end up, so as to clear the heads of other persons.

When pipe is transported on a vehicle, a red warning flag should be placed on the projecting ends.

When carrying a long and heavy pipe, each member of the crew should exert the utmost care to work together as a team, while observing the following precautions:

1. All members of the crew should understand the signals for lifting and lowering.
2. Each man should make sure that his feet are in the clear.
3. When the use of tools is appropriate, use either tongs or a carrying bar with a U-shape bend to fit the pipe. When men are carrying a length of pipe on their shoulder or at waist level, they should all carry it on the same side.
4. Take a firm grip on the lifting bar or tongs.
5. Lift at a given signal of the supervisor or co-worker, with all members of the crew lifting and moving together.
6. Carry the load without sudden starts or stops; move slowly and take care to place the feet firmly.
7. Stop at the appointed place, and wait for the supervisor's or co-worker's signal to lower.

8. Lower the load carefully, bending at the knees as in lifting, and lower slowly along with all the other members of your crew.

Use caution in handling THREADED pipe. The threads are always sharp and will cut the flesh easily. Do not put the hands inside the pipes.

When removing pipe, work from the top end of the pile as much as possible. Pipe larger than two inches in diameter should be handled by means of a hardwood pipestick.

Use block and tackle, chain falls, or other lifting devices, where appropriate, in handling heavy pipes and fittings.

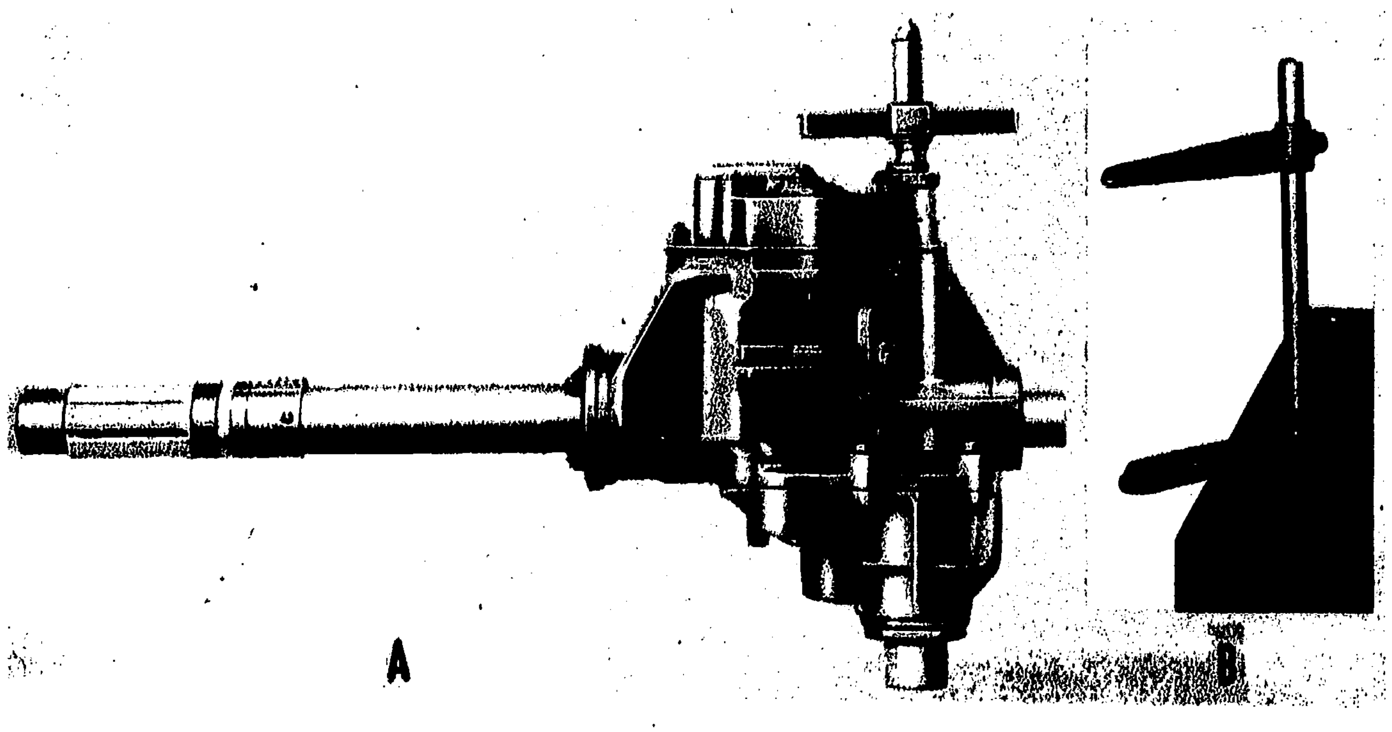
EXCAVATIONS

Maintenance operations on distribution systems often may involve excavation. Some of the main precautions to be observed in making excavations are:

1. Wear a protective hat when working in a trench.
2. Keep a safe distance from other workers to avoid the danger of striking them with tools.
3. Do not jump into a trench, but sit on the shoulder and slide in, if the trench is shallow. Use ladders where required (e.g., where trench is 5 feet or more in depth). Before climbing out of a trench, look all ways for traffic danger.
4. Remove earth and other material in such a way that overhanging banks are avoided. Do not go under an overhanging bank and, when working near one, be very cautious. If it is necessary to remove an overhanging bank, work from one side to the center, always facing the point of danger.
5. Where necessary, shore trench walls.
6. If undercutting is necessary, provide adequate bracing, and restrict the public from all braced areas.
7. Where practical, place excavated material at least 2 feet away from the edge of the excavation; otherwise provide bracing if necessary.
8. Keep all tools, working material and loose objects away from the shoulder of the trench.

SPECIAL TOOLS

As a Utilitiesman, you should have a thorough knowledge of the special tools and equipment used in your job. In this section we will explain some of the special tools which are not covered in Tools and Their Uses, NavPers 10085-B nor



11.6(28B)

Figure 5-22. — Heavy duty pneumatic drill and stand.

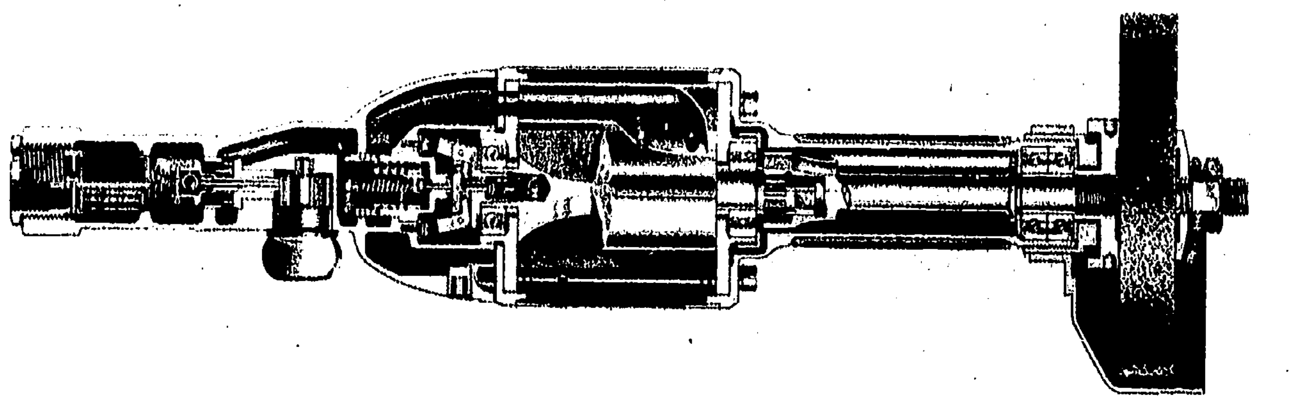


Figure 5-23. — Sectional view of a pneumatic grinder. 11.8(28B)X

in Constructionman, NavPers 10630-E. Some of the special tools are: portable power tools; power hacksaws; power-actuated tools; and pneumatic pavement breakers.

PORTABLE POWER TOOLS

In the shop or field, you will be using portable power drills, hammers, and grinders. You should be thoroughly familiar with the operation and care of these tools and with all applicable safety precautions. Only the portable power tools not covered in Tools and Their Uses are discussed in this chapter.

The portable power tools that you use may be powered by electric motors or by air (pneumatic) motors. Whether electric-powered or air-powered, the tools are essentially the same and the procedures for using them are the same. This section deals primarily with pneumatic drills and pneumatic grinders since these are probably the most widely used portable power tools. As a Utilitiesman, you will be required to maintain the portable pneumatic tools as well as to use them.

All low-pressure compressed air systems should have a filter, regulator, and lubricator assembly installed at the outlet. This assembly will ensure delivery of clean regulated, mist lubricated compressed air for the operation of pneumatic tools.

Before using any pneumatic tool, connect the airhose to the low-pressure compressed air outlet and blow out any foreign matter that may be in the airhose. Then connect the hose to the pneumatic tool and turn on the air at the compressed air outlet. Turn on the tool, and test its operation.

The heavy duty PNEUMATIC DRILL, shown in view A of figure 5-22, is reversible. Its speed can be closely controlled by means of the throttle valve located in the handle. The variable speed feature of this drill makes it particularly useful for heavy duty drilling in places that are hard to reach.

Another feature of this drill is that it has a feed screw which can be used in conjunction with a special type of drill stand called OLD MAN. This drill stand is shown in part B of figure 5-21. When you drill a hole using the pneumatic drill with the OLD MAN, make sure you wear goggles during the drilling operation. In drilling, first place the twist drill in the socket. Then adjust the feed screw in the machine to its lowest position and place the point of the feed screw in one of the indentations in the arm. Drill the hole to the required depth. Watch the drill, and when it begins to come through, decrease the speed. Hold the drill up by hand so that it will not drop onto the work.

The PNEUMATIC GRINDER, shown in figure 5-23, operates on the same basic principle as the pneumatic drill. It can be equipped with either a grinding wheel or a wire bristle wheel. After attaching the appropriate wheel, perform the preliminary steps required to connect the pneumatic grinder. Always run this machine so the ginding surface of the wheel is square with the surface of the material being ground.

Pneumatic tools must have thorough lubrication. The moving parts of a pneumatic tool are very closely fitted; if proper lubrication is neglected, they wear rapidly and in a short time fail to work.

Valves and pistons on pneumatic hammers required a light machine oil; since the compressed air comes directly in contact with these parts, it has a tendency to drive the lubricant out through the exhaust.

When working steadily with a pneumatic tool, you should regularly check the lubricator to make certain there is ample lubricant available and empty the filter assembly when needed. On low-pressure compressed air systems that do not have the filter, regulator and lubricator assembly installed, you should disconnect the airhose every hour or so and squirt a few drops of light oil into the airhose connection. Don't use heavy oil, or you will "gum up the works" and have operating troubles. If this happens, you will have to clean your tool in cleaning solvent to loosen the gummy substance. Blow out the tool with air, lubricate it with a light oil, and go back to work.

Keep your pneumatic tools clean and lubricated and you will have fewer operating troubles.

When using portable power tools, there are certain safety precautions that must be observed. These include the following:

1. Always wear your goggles when working with these tools.

2. Take care not to allow any of these tools to run out of hand. The pneumatic grinder especially will want to "walk" away from the point you want to grind.

3. Always stand so that your feet won't slip while you are working and so that you are properly balanced.

4. Apply the grinding wheel to the work with gentle pressure. Sudden forcing may cause the wheel to disintegrate. As you complete the work, ease up on the pressure.

5. With all pneumatic tools, be careful not to allow the airhose to become kinked.

6. When using an electric tool, make sure that the tool is properly grounded. Use only 3-wire grounded cords and plugs.

7. When an extension cord must be used, in addition to the cord on an electric tool, the extension cord must not be energized when the tool plug is inserted in or removed from the extension cord. Use only 3-wire cord and grounded plugs.

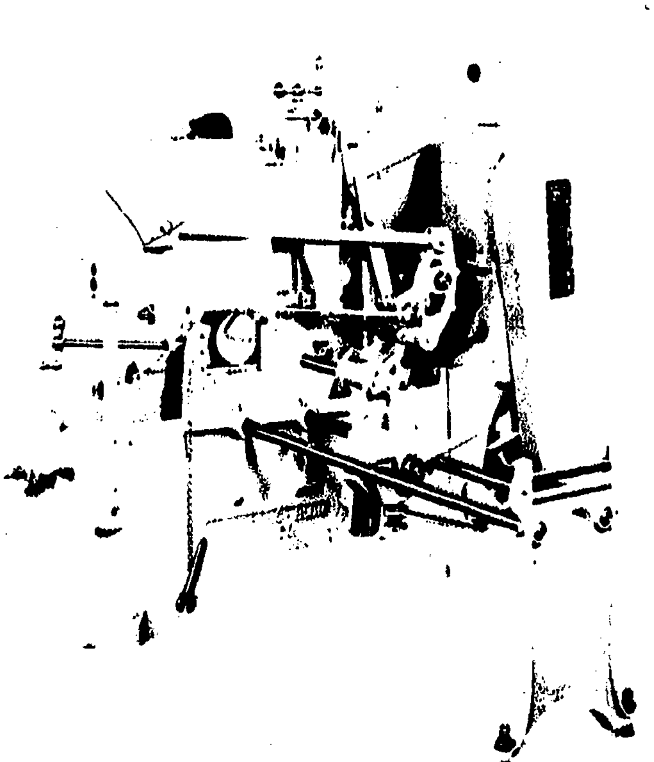
POWER HACKSAWS

The power hacksaw is found in all except the smallest shops. It is used for cutting bar stock, pipe, tubing, or other metal stock. The power hacksaw, shown in figure 5-24, consists of a base, a mechanism for causing the saw frame to reciprocate, and a clamping vise for holding the stock while it is being sawed. There are two types of power hacksaws, the direct mechanical drive and the hydraulic drive.

The capacity designation of the power hacksaw illustrated is 4" x 4". This means that it can handle material up to 4 inches in width and 4 inches in height.

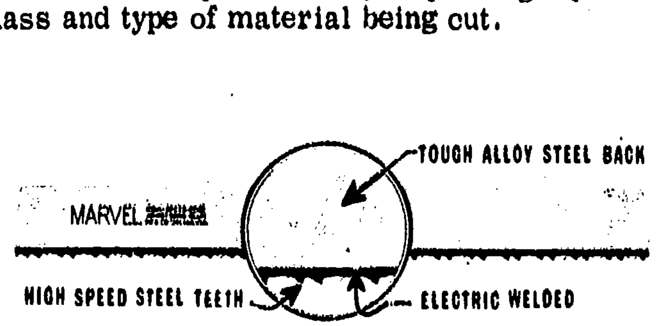
There are three types of feed, as follows:

1. Mechanical feed, which ranges from 0.001 to 0.025 inch per stroke, depending upon the class and type of material being cut.



11.18(28B)X

Figure 5-24. — Power hacksaw.



11.19X

Figure 5-25. — Power hacksaw blade.

133.78(127E)
Figure 5-26. — Power-mate stud driver.

2. Hydraulic feed, which normally exerts a constant pressure but is so designed that when hard spots are encountered the feed is automatically stopped or shortened to decrease the pressure on the saw until the hard spot has been cut through.

3. Gravity feed, which provides for weights on the saw frame. These weights can be shifted to increase or decrease the pressure of the saw blade on the material being cut.

All three types of feed mechanisms lift the blade clear of the work during the return stroke.

Hacksaw Blades

The blade shown in figure 5-25 is especially designed for use with the power hacksaw. It is made with a tough alloy steel back and high speed steel teeth, a combination which gives both a strong blade and a cutting edge suitable for high speed sawing.

These blades vary as to the pitch of the teeth (number of teeth per inch). The correct pitch of teeth for a particular job is determined by the size of the section, and the material to be cut. Use coarse pitch teeth for wide, heavy sections in order to provide ample chip clearance. For thinner sections, use a blade with a pitch that will keep two or more teeth in contact with the work so that the teeth will not straddle the work. Such straddling will strip the teeth. In general, you should select blades according to the following information:

1. Coarse (4 teeth per inch), for soft steel, cast iron, and bronze.

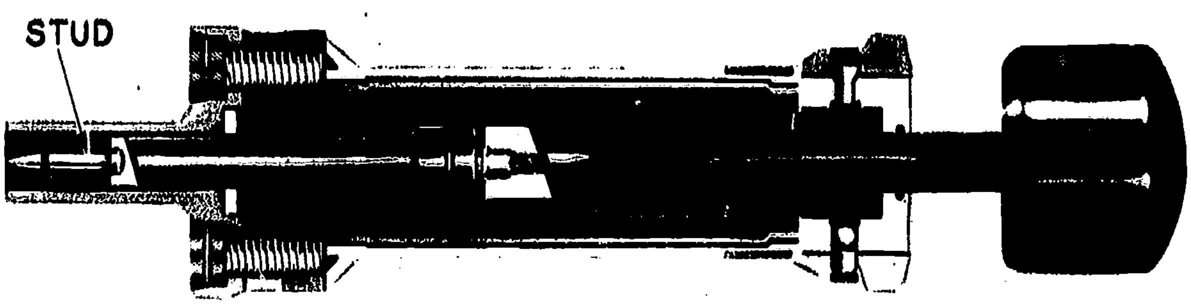
2. Regular (6 to 8 teeth per inch), for annealed high carbon steel and high speed steel.

3. Medium (10 teeth per inch), for solid brass stock, iron pipe, and heavy tubing.

4. Fine (14 teeth per inch), for thin tubing and sheet metals.

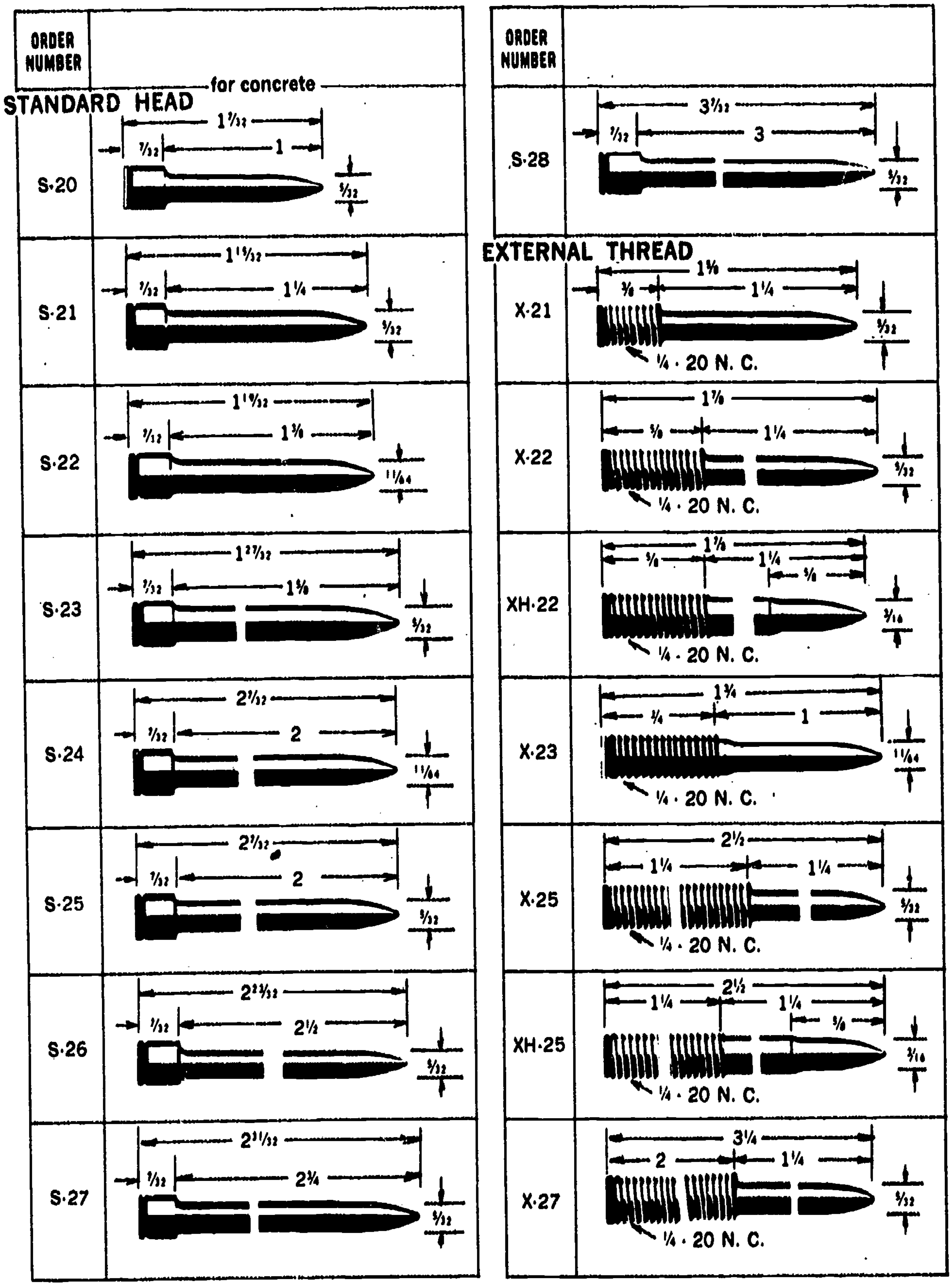
Speeds and Coolants

Speeds on hacksaws are stated in strokes per minute--counting, of course, only those strokes which cause the blade to come in contact with the stock. Speed changing is usually accomplished by means of a gear shift lever. There may be a card attached to your equipment or near it, stating recommended speeds for



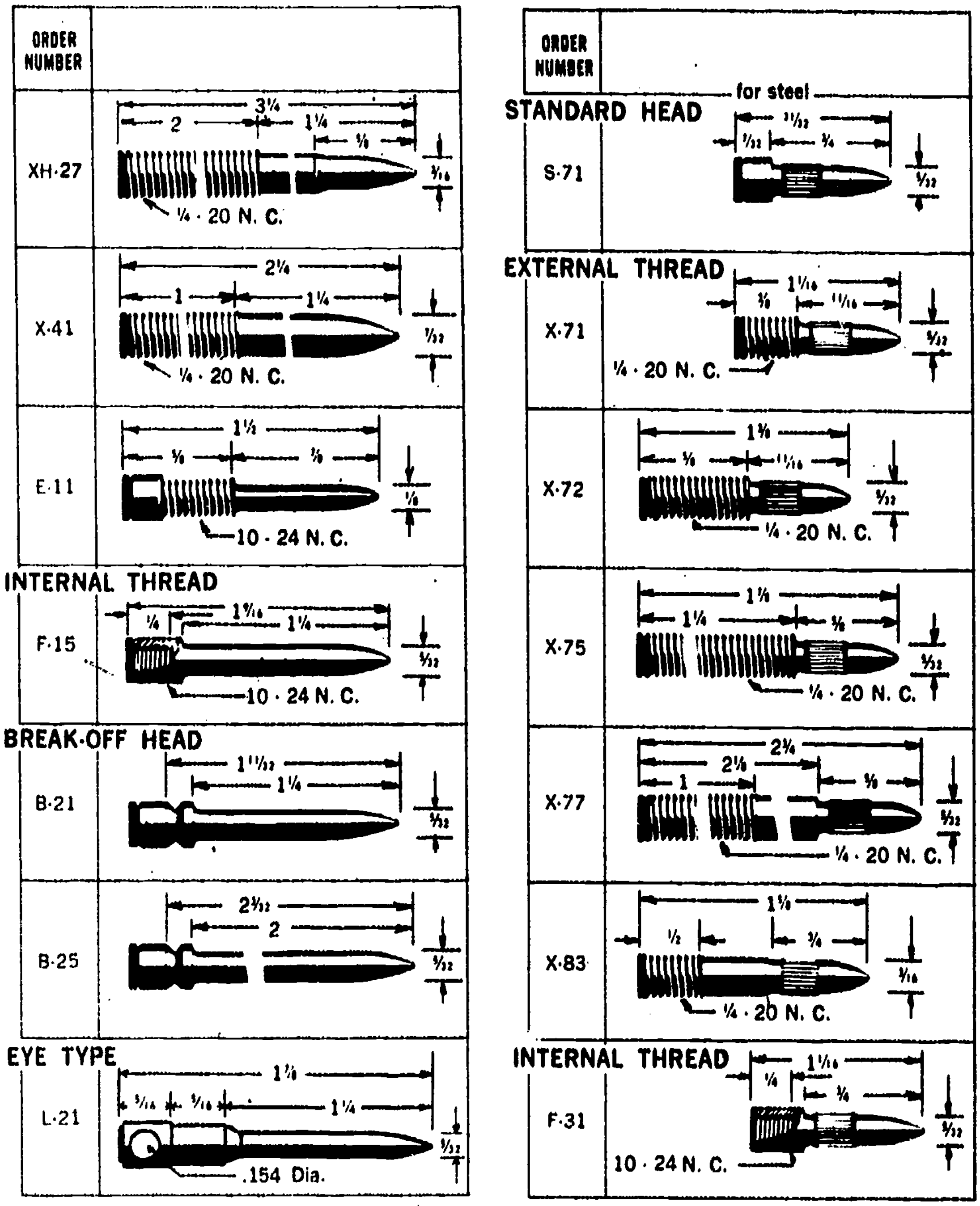
133.78X

Figure 5-27. — Cutaway view of power-assisted stud driver.



29.121.2

Figure 5-28.—1/4" headed pins and threaded studs.



22 CALIBER STANDARD—Wad

ORDER NUMBER	LOAD LEVEL NUMBER	WAD COLOR
22w3	3	Green
22w4	4	Yellow
22w5	5	Red
22w6	6	Purple

22 CALIBER SPECIAL-Wad

ORDER NUMBER	LOAD LEVEL NUMBER	WAD COLOR
22w7	7	Gray
22w8	8	Brown

25 CALIBER STANDARD—Wad

ORDER NUMBER	LOAD LEVEL NUMBER	WAD COLOR
25w6	6	Purple
25w7	7	Gray

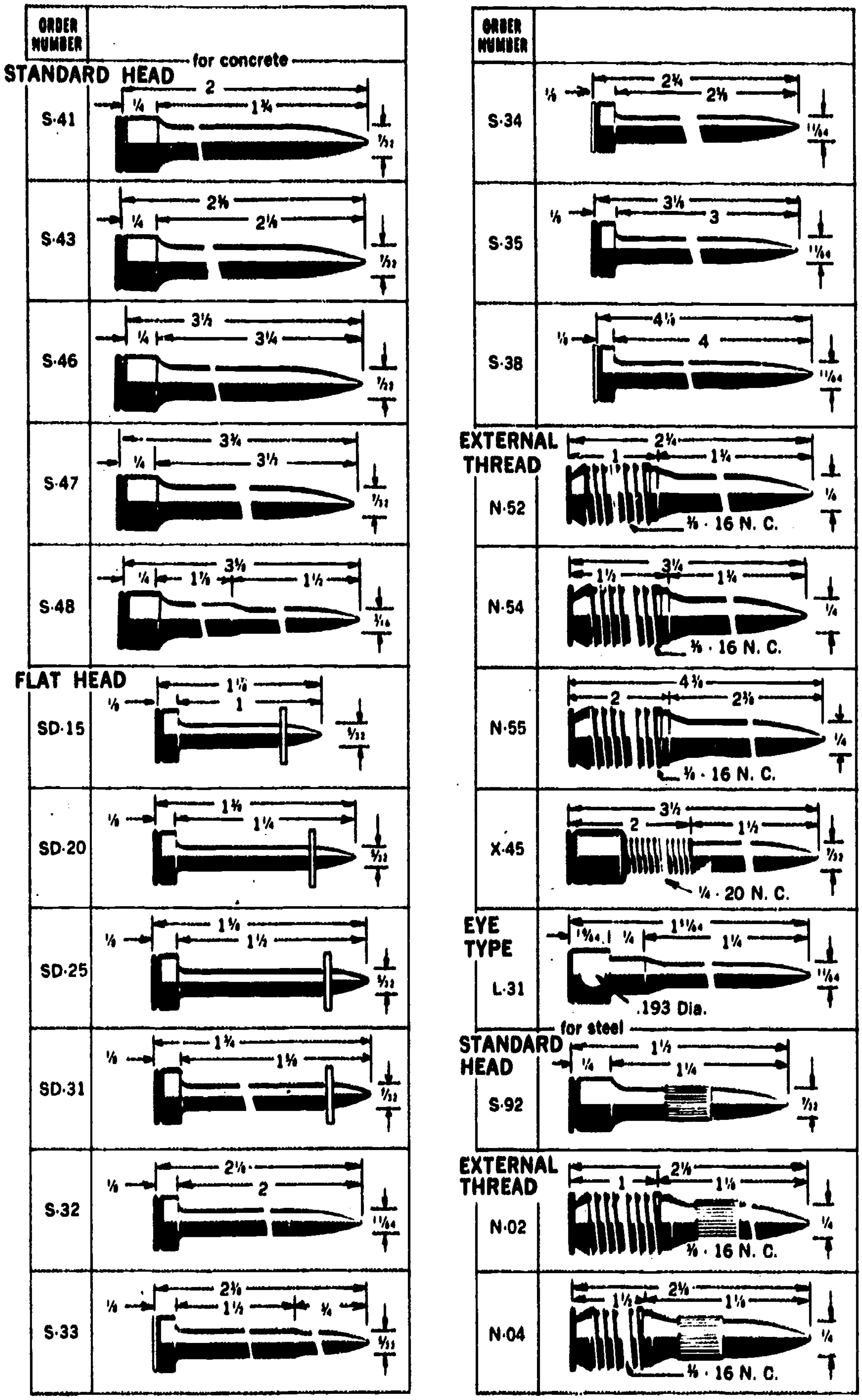
25 CALIBER STANDARD—Crimp

ORDER NUMBER	LOAD LEVEL NUMBER	HEAD COLOR
25c1	1	Gray
25c2	2	Brown
25c3	3	Green

32 CALIBER STANDARD—Wad

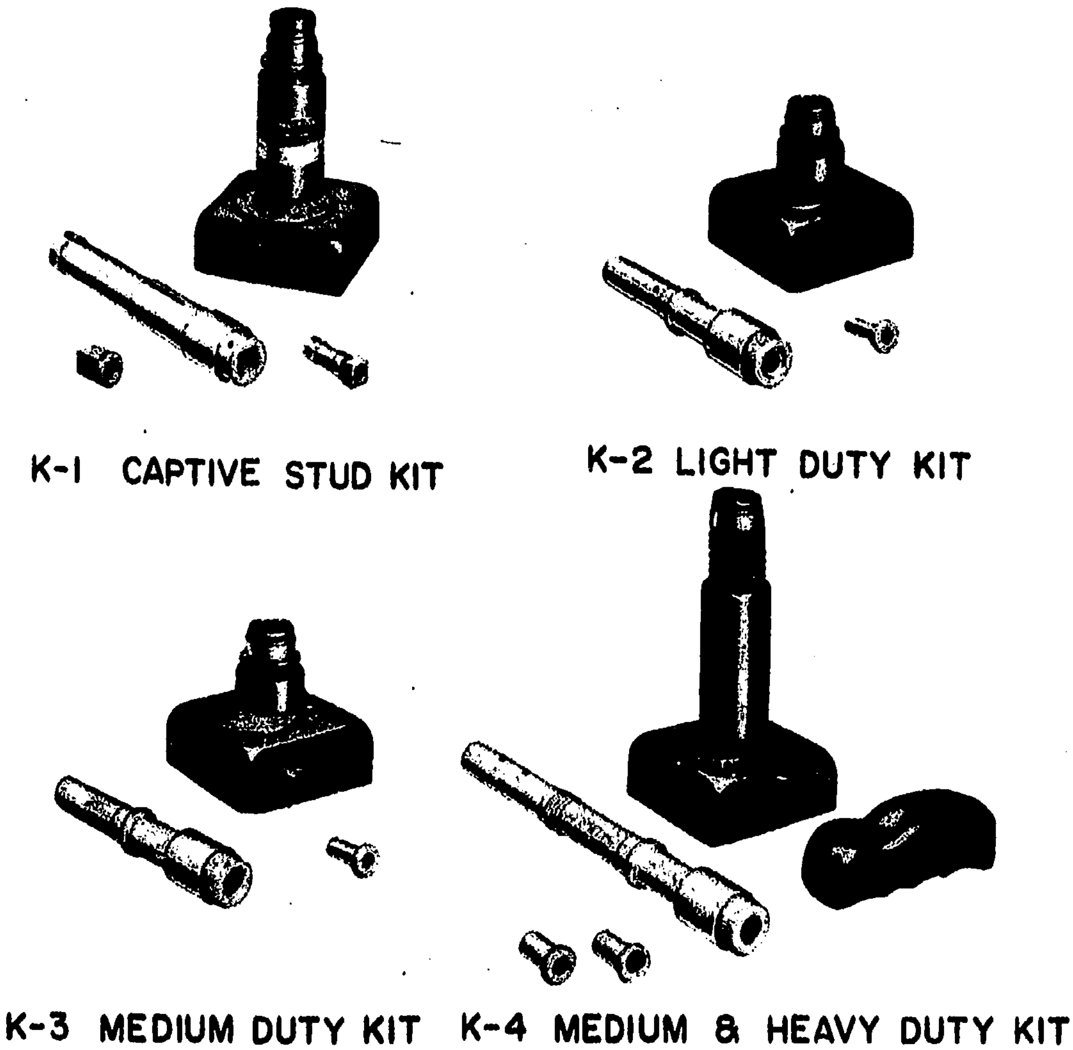
ORDER NUMBER	LOAD LEVEL NUMBER	WAD COLOR
32w8	8	Brown
32w9	9	Green
32w10	10	Yellow
32w11	11	Red

Figure 5-28. —1/4" headed pins and threaded studs—continued. 29.121.2



29.121.3

Figure 5-29. — 3/8" headed pins and threaded studs.



133.340.1

Figure 5-30.—Stud driver kits.

cutting various metals. The following speeds, however, can usually be used:

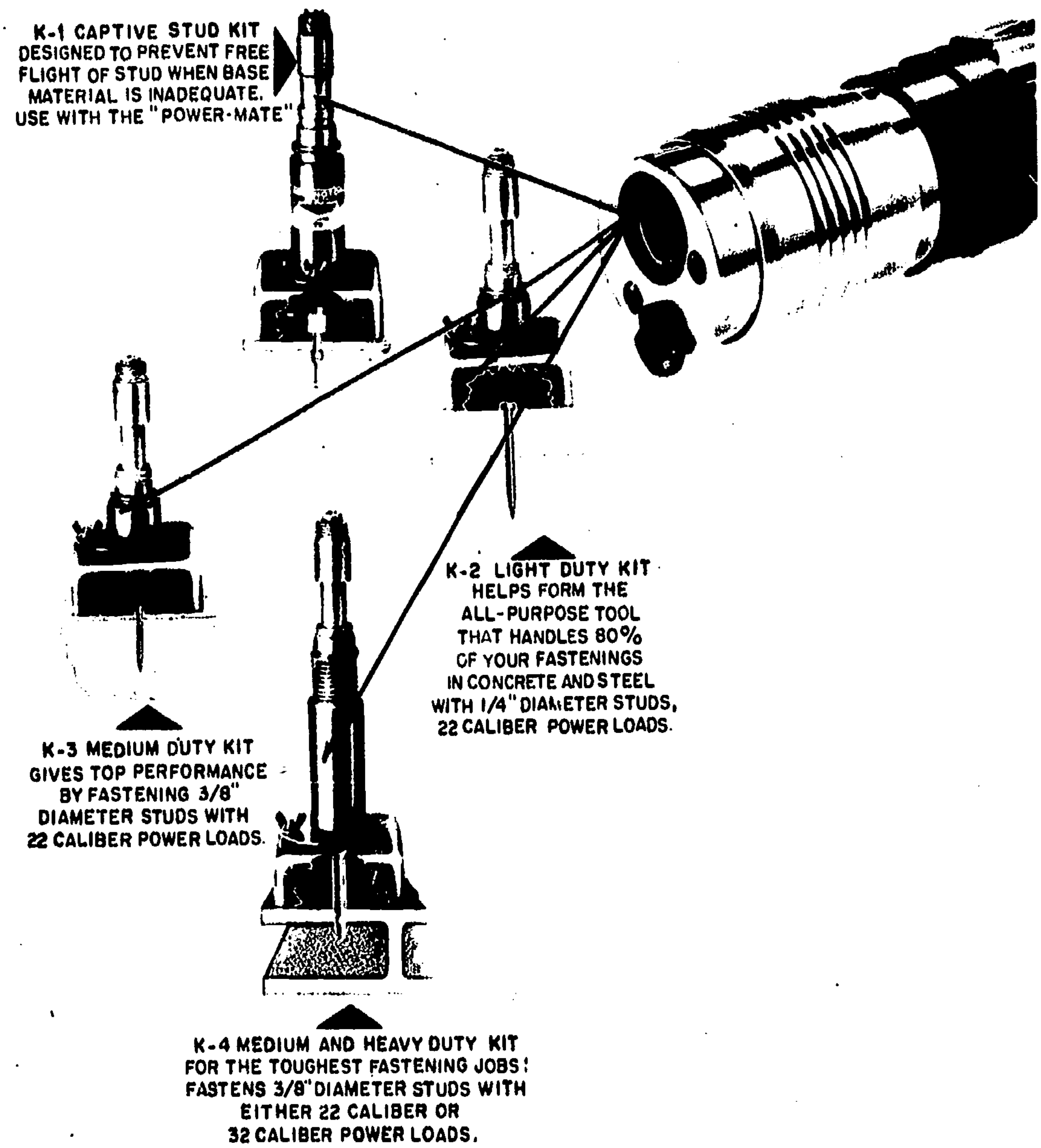
1. Cold rolled or machine steel, brass, and soft metals—136.

2. Alloy steel, annealed tool steel, and cast iron—90.

3. High speed steel, unannealed tool steel, and stainless steel—60.

Cast iron should be cut entirely dry, but a coolant should be used when cutting all other materials. A suitable coolant for most metals is a solution of water and enough soluble oil to make the solution white. The coolant not only prevents overheating of the blade and stock but also serves to increase the cutting rate.

When you operate the power hacksaw, place the pipe in the clamping device, adjusting it so that the cutting off mark is in line with the blade. Next, turn the vise lever to clamp the pipe in place, being sure that the material is held tightly, and then set the stroke adjustment. Before you start the machine, check and see that the blade is NOT touching the pipe. Blades can be broken if you do not follow this rule. Feed the blade slowly into the work, and adjust the coolant nozzle so that it directs the fluid over the saw blade. Safety precautions to be observed while operating this tool are posted in the shop. Read and observe them.



133.340.2

Figure 5-30.—Stud driver kits—continued.

POWDER-ACTUATED TOOLS

A number of different kinds of tools which utilize explosive charges to drive fastening devices are widely used. These tools are sometimes called stud guns, stud-type cartridge guns, builder's guns, or powder-actuated guns. Among the number of different tools, there are two basic types in use by the Navy. One type (fig. 5-26) is a high-velocity device in which the fastener is shot down the barrel of the tool by a relatively powerful powder charge. Another type (fig. 5-27) is a power-assisted hammer-drive tool operating on the low-velocity principle. The manufacturers of the different types of tools provide detailed instructions for the safe and effective use of their products so follow their instructions closely at all times.

The powder-actuated tool in figure 5-26 may be new to you, because it has not been in the system as long as the one shown in figure 5-27. The powder-actuated tool in figure 5-26 covers the complete range of powder-actuated fastening, providing light, medium- and heavy-duty anchoring of 1/4" and 3/8" headed pins and threaded studs in masonry and steel. (See figs. 5-28 and 5-29 for the proper pins and studs.) The barrel on this type powder-actuated tool can

133.79X
Figure 5-31. — Toenailing wood to hollow metal decking.

133.81X
Figure 5-32. — Fastening channel to concrete.

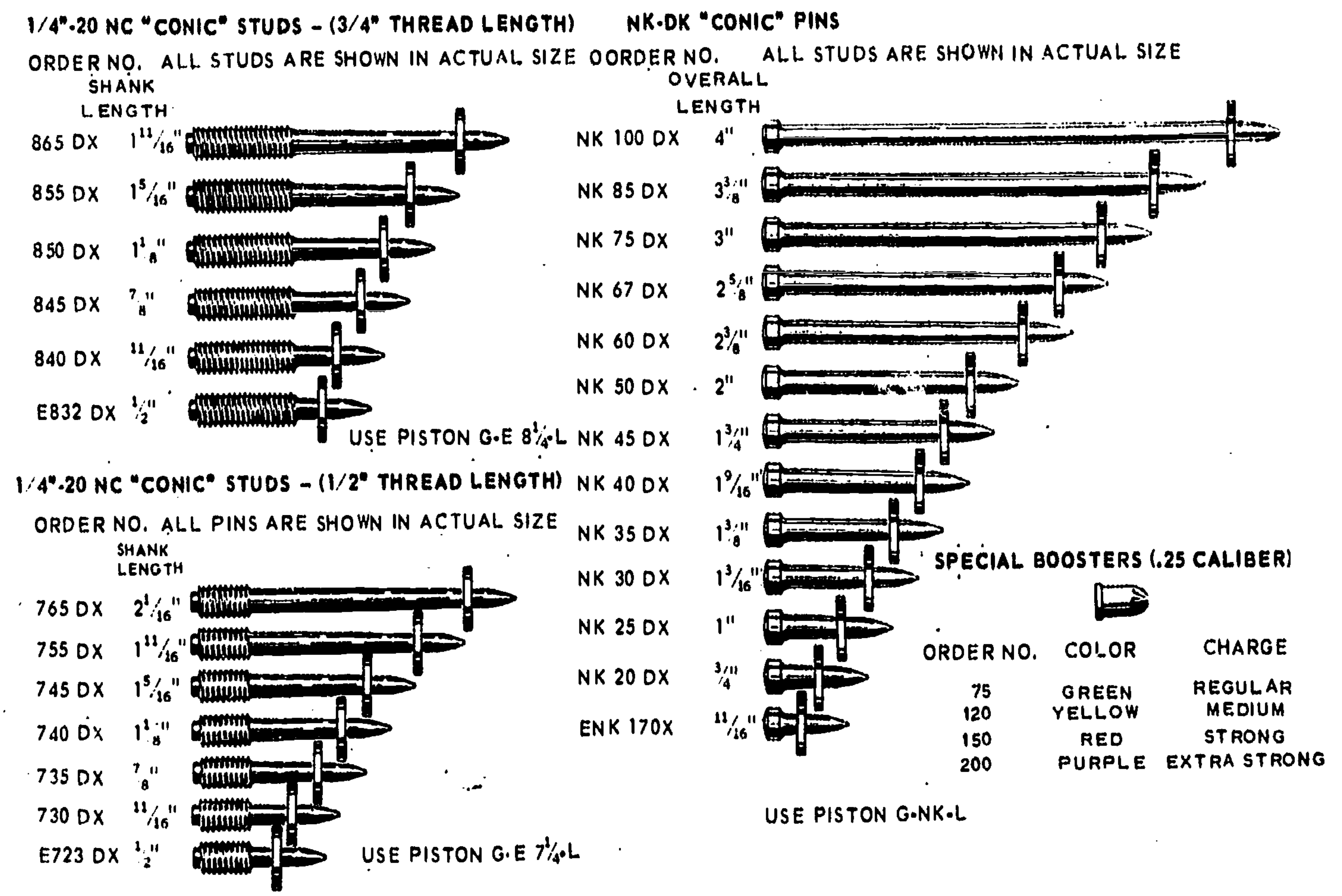
be changed in a matter of seconds, so as to adapt the tool to either of the kits described in figure 5-30. This can be a difficult and dangerous tool to use so be sure to study the manufacturer's manual befoi enand.

The power-assisted stud driver shown in figure 5-27 may be used either with or without the powder charge. When the powder charge is used, it acts as a booster for a hammer blow. Without a powder charge, the device may be used as an ordinary hammer-drive tool. The stud, shown in the lower part of figure 5-27 is seated, guided, and controlled in the recessed piston. The rim-fire booster blank, which contains a small slow-burning charge of powder, is seated backwards above the piston and below the ram, which is hit with the hammer. Rather than shooting the stud at high velocity, the captive, heavy-mass piston pushes the stud into the work at a relatively low velocity. The piston guides the head of the fastener from the start to the finish of driving. A washer or guide disk near the end of the pin or stud guides the fastener during operation. Since the piston is captive, no energy is imparted to the fastener after the piston stops travelling. The depth of penetration varies with the type of piston and fastener used. Over-penetration is prevented by the positive control of the fastener exercised by the piston and guide disk. The hazards inherent in using the high-velocity gun are eliminated by the use of this type of tool; special shields or protective devices are not generally considered necessary.

The power-assisted hammer-drive tool seems to be highly popular because it may be used in any position: on the deck, on the wall, in the overhead. It may be used to fasten almost any type of construction material to any other type. Figure 5-31 shows a wood-to-metal connection.

Figure 5-32 shows a metal-to-concerte connection.

Figure 5-33 shows some of the other types of widely used pins and studs. The tool illustrated in figure 5-27, will accommodate fasteners of up to 4-inch overall length. For most jobs you will need two pistons: one for pins and one for studs. However, if you have studs with two different thread lengths (such as shown in fig. 5-33), you will need a separate piston for each thread length. There are many other types of fasteners for special requirements. They may be used in the hammer-drive tool



29.121X

Figure 5-33. — Studs and pins.

if you order the special piston that is needed for the fastener.

Safety is a very important factor in the use of powder-actuated tools. These tools should be operated, repaired, serviced, and handled only by UTs who have been trained and certified by the manufacturer, his authorized representative, or Navy Department certified instructors. Therefore, special authorization or licensing is required before you are permitted to use most types of stud guns. Never attempt to use one of these tools without proper authorization and instruction. Be sure you follow the manufacturer's instructions. Never use the powder charge in an explosive atmosphere. Lastly, remove any defective tools or parts from service immediately.

PNEUMATIC PAVEMENT BREAKER

In making repairs to underground water and sewage systems, it may be necessary at times to excavate in paved areas. On such occasions you will find the pneumatic pavement breaker, commonly referred to as a pneumatic hammer or jackhammer, a very useful tool for breaking up the concrete or asphalt pavement. It is also used to dig in dense soil or clay and for other purposes. The pavement breaker which you will use is powered by a compressed air (pneumatic) motor. The operating procedure, maintenance, and safety precautions applicable to the pavement breaker are covered in the Constructionman, NavPers 10630-E, so refer to that manual if you are not familiar with this tool.

CHAPTER 6

PRIME MOVERS, PUMPS AND AIR COMPRESSORS

Prime movers, pumps, and air compressors are used by the UT in various phases of his job. This chapter provides information that will aid the UT in carrying out duties that involve the installation, operation, and care of prime movers, pumps, and air compressors.

Due to the diversity of prime movers, pumps, and air compressors used throughout the Navy, our discussion of operating procedures and maintenance requirements must necessarily be brief and general. We will concentrate primarily on the fundamental operating principles and parts of prime movers, pumps, and air compressors, and some of the operating difficulties to which they are susceptible.

Specific operator maintenance schedules, logs, and reports are developed in each local command. Each local command should also maintain a file of manufacturer's instructions, parts lists, drawings and diagrams for all equipment installed or used in that command. Taken together, these maintenance schedules, manufacturer's instructions, and so on, will provide you with detailed information on operating procedures and maintenance requirements. In all cases, you should be thoroughly familiar with these guides before attempting to operate and maintain the equipment for which you will be responsible.

Brief mention should be made of several Navy training publications. Although these books are described as basic texts, the information they contain can considerably enhance your understanding and knowledge of the equipment covered in this chapter. Basic Electricity, NavPers 10086-B, will provide you with a comprehensive treatment of the operating principles and construction of electric motors. Basic Machines, NavPers 10624-A, contains a detailed explanation of the operating principles and construction of internal combustion engines. In the case of pumps and air compressors, Fluid Power, NavPers 16193-B, gives an excellent discussion of fluid physics, the construction and operating principles of pumps and air compressors, and covers such related topics as valves, packing, fluid piping and tubing, and fluid temperature and pressure gages.

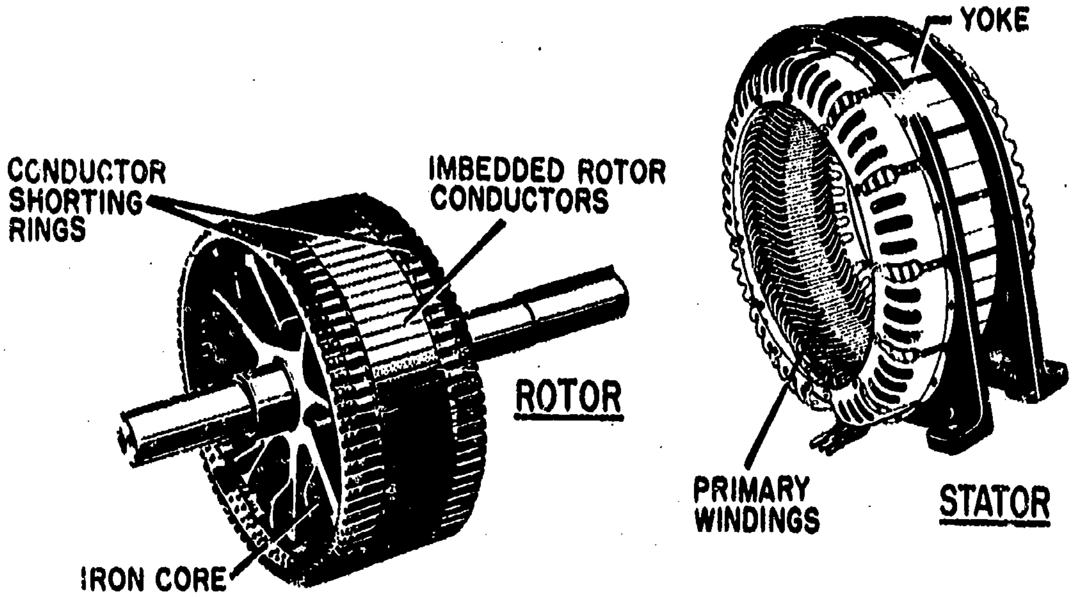
PRIME MOVERS

A "prime mover" may be defined simply as a source of mechanical energy or power. The mechanical energy produced by the prime mover is transmitted to another machine or mechanism, such as a pump or air compressor, to accomplish some form of useful work. In this sense, prime movers are sometimes referred to as driving equipment. The mechanism or linkage which transmits the mechanical power developed by the prime mover is called the drive. You are perhaps most familiar with electric motors and internal combustion engines insofar as they are used as prime movers. Although we will discuss the prime mover in this chapter as a separate topic, you will operate and maintain it in conjunction with some driven mechanism (pump, air compressor, etc.).

ELECTRIC MOTORS

Electric motors, in functioning as prime movers, receive electrical energy from some external source and transform it into the mechanical energy needed to turn out work. Electric motors may be broken down into two broad categories: direct current (d.c.) motors and alternating current (a.c.) motors. Since most of the electrical power generating systems both ashore and afloat produce alternating current, our discussion of electric motors will be confined to the a.c. motor.

Various types of a.c. motors are available, but as a Utilitiesman, you will be working primarily with the rotating-field INDUCTION type a.c. motor. The popularity of this motor is due largely to its reliability and simplicity of construction. The basic induction motor has two



73.160:77.77

Figure 6-1.—Rotor and stator assemblies of an induction motor.

main assemblies or components, a STATOR and a ROTOR, shown in figure 6-1. The mechanical rotation of the rotor is produced through the principle of electromagnetic induction. Alternating current flows through the stator (a circular assembly of stationary coils or windings) which surrounds the rotor. The alternating current flow in the stator produces a constantly rotating magnetic field. This magnetic field induces a current flow in the conductors of the rotor (a cylindrical or drum-like assembly of copper bars mounted on a shaft). The induced current in the rotor then produces a magnetic field of its own. The magnetic field of the rotor is produced in such a way that it opposes the magnetic field of the stator; that is, the two fields repel each other. This continuous repulsion of the rotor field by the stator field results in a continuous rotation of the rotor assembly around its axes or shaft. Thus, we have electrical rotation (in the stator) transformed into mechanical rotation (at the rotor).

The rotational speed of the stator field will remain constant, unless the frequency of the electrical power source should vary for some reason. The rotational speed of the rotor is likewise constant, and is more or less independent of the work load imposed on it. This is not to say, however, that an induction motor cannot be overloaded. Under heavy or excessive loads, the motor tends to draw more current in order to maintain speed. This can result in overheating and burnt-out windings.

Induction motors are usually named according to the method of starting the motor. Two fairly common types of induction motors, classified in this manner, are the SPLIT-PHASE MOTOR and the CAPACITOR-START MOTOR. Split-phase induction motors are designed to operate on single-phase current. Induction motors require two or more out-of-time-phase currents in order to produce the continuously rotating magnetic field in the stator. For this reason, induction motors which must run on a single-phase power supply are provided with split-phase windings which, in effect, divide the single-phase current into the two phases necessary. Split-phase motors can be used to drive a variety of equipment, such as washing machines, oil burners, small pumps, and blowers. The capacitor-start induction motor is a variation of the split-phase motor. It has the added advantage of a high capacity, electrolytic capacitor. Briefly, this is a device which stores electricity in order to provide more power during the start.

In addition to the foregoing classifications, there are a number of mechanical modifications to induction motors, three of the most important ones being (1) the splashproof motor, (2) the totally enclosed fan-cooled motor, and (3) the explosion-proof motor.

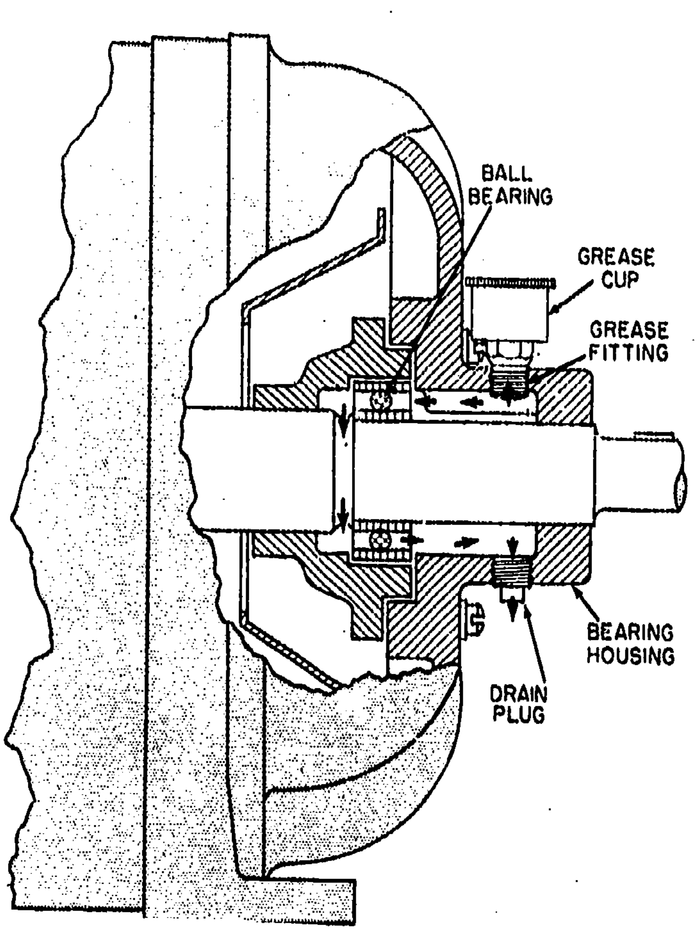
The splashproof motor is constructed so that dripping or splashing liquids will not enter the motor. The motor is self-ventilated, but since moisture-saturated air may be circulated through the motors, the windings are made moisture resistant. Motors of this type are most often used to drive pumps and other machinery where the moisture content of the air is high.

The totally enclosed, fan-cooled motor has totally enclosed windings and rotor. Cooling air is circulated over the enclosure to carry away heat. This motor is used in locations where the surrounding air may contain a high proportion of dust, as in a carpenter shop.

The explosion-proof motor is similar to the totally enclosed, fan-cooled motor, but is constructed to prevent any explosion within the motor from igniting combustible gases or dust in the surrounding air. This motor, therefore, is used in sewage treatment plants and at other locations as a safety consideration.

Operation and Maintenance of Electric Motors

The operation and operator maintenance of electric motors has three main aspects: lubrication of moving or rotating parts, cleanliness of windings and rotor, and proper alignment of drives. Careful attention to these factors is necessary to ensure motor efficiency and, in many cases, prevent motor breakdown.

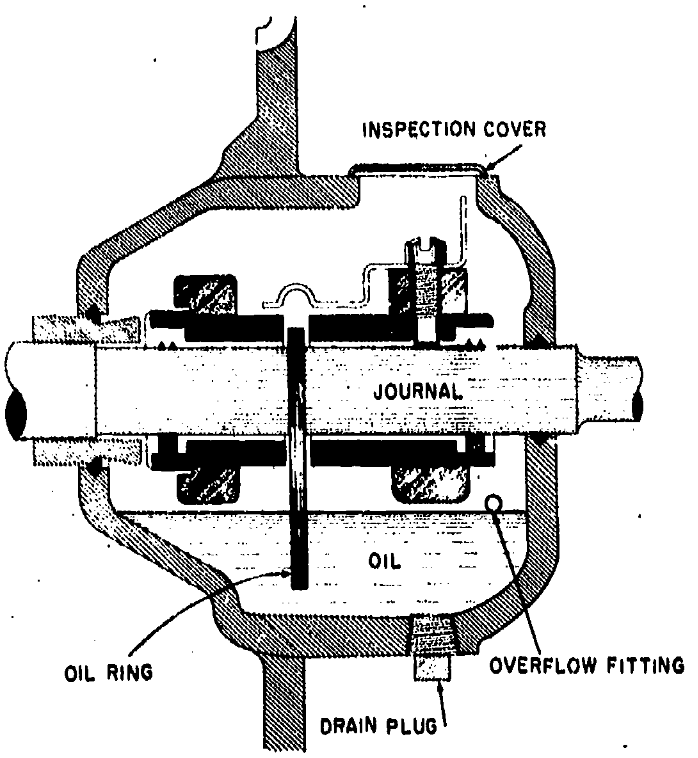


77.68
Figure 6-2.—Grease-lubricated ball bearings.

LUBRICATION.—Electric motors can be fitted with a variety of bearings, such as sleeve bearings, roller bearings, and ball bearings. The purpose of these bearings is to reduce friction, and in order to remove the heat generated by friction, the bearings must, of course, be lubricated. The lubricant is usually either grease or oil. Some motors may be equipped with ball bearings which are permanently lubricated or packed with grease when the motor is assembled at the factory. These bearings are usually covered with a nameplate which reads: DO NOT LUBRICATE. Most electric motor bearings, however, must be lubricated at frequent intervals. In such cases the lubricant may be fed to the bearings through a pressure fitting or grease nipple from a hand-operated grease gun. Or, the lubricant may be metered to the bearings from a grease or oil cup, which must be periodically turned or screwed down by hand to keep the bearing supplied with lubricant (see fig. 6-2).

Some rotating shafts may be fitted with sleeve bearings which usually are in the form of soft brass cylinders that fit around the machined shaft journal like a sleeve. In some installations, the lubricating oil is circulated through the sleeve bearing under pressure. Some sleeve bearings, however, may be lubricated by means of an oil ring or rings, as illustrated in figure 6-3. The weight of the ring hanging on the journal is sufficient to cause it to revolve as the shaft revolves. As the oil ring rotates, it dips into an oil reservoir located directly beneath the shaft journal. The oil picked up by the ring in this manner is then diffused along the shaft, between the shaft journal and sleeve bearing. Proper lubrication of ring-oiled sleeve bearings will depend on maintaining a sufficient oil level in the reservoir. For this reason, most sleeve bearings will have oil filler gages or overflow fittings installed to aid the operator in maintaining the oil at a proper level.

While the electric motor is in operation, the operator will be required to make frequent checks and inspections for proper lubrication



77.65
Figure 6-3.—Ring-oiled sleeve bearing.

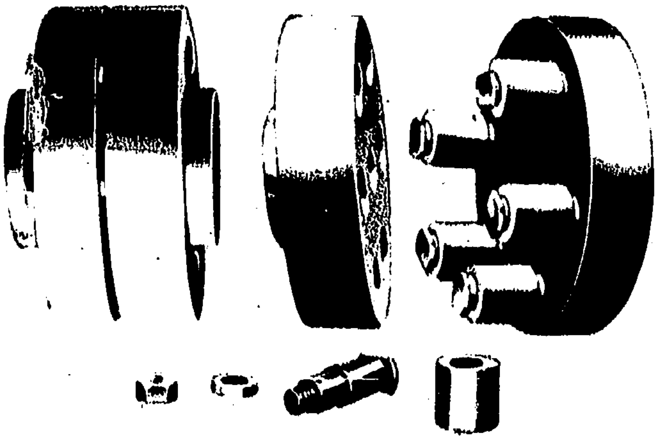
of bearings or any indication of bearing overheating. This will usually involve checking for heat radiated to the hand or by inspecting thermometers. It is interesting to note that one of the most frequent causes of bearing overheating is overlubrication. This applies in particular to grease-lubricated bearings. When an excessive amount of grease accumulates around the bearings, it serves as insulation and seriously hinders the conduction of heat away from the bearing. The specific lubrication requirements and inspection procedures may vary somewhat according to the type of bearings and the particular motor installation. In any event, local operator maintenance schedules and instructions will provide you with detailed guidance in this respect. In addition to the inspections outlined above, the operator should also be constantly alert for any leakage of lubricant from the bearings, particularly lubricant that is creeping toward the windings or other electrical conductors.

At less frequent intervals, maintenance schedules may require additional and more detailed inspections for proper lubrication. This may or may not involve dismantling parts of the bearing housing. In addition, bearing housings and pressure fittings must be cleaned periodically. In the case of grease-lubricated bearings, old grease must be flushed from the bearing with solvent and fresh grease added. Sleeve bearings must be examined at various intervals, and the oil reservoir flushed, cleaned, and refilled.

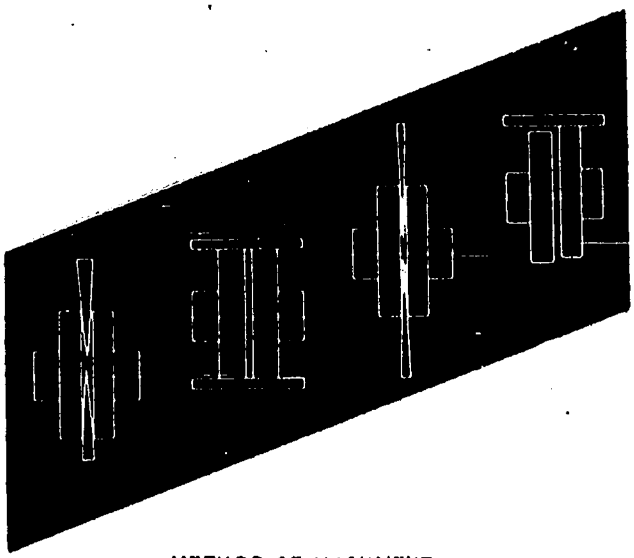
CLEANLINESS.—This aspect of electric motor operation and maintenance is largely a matter of prevention rather than inspection and correction. As an operator, you must develop meticulously clean housekeeping and maintenance habits. Dirt, dust, and other foreign objects which accumulate on and inside an electric motor can reduce ventilation and may foul moving parts. When dirt and grit accumulate on windings, the cooling or ventilation of these electrical conductors is seriously reduced. During the various inspection routines, you must exercise care to prevent lubricants and lubricant fittings from getting contaminated. Dirt in lube oil will, in many cases, settle to the lowest point in the system before doing any extensive damage. However, dirt or grit that gets into lubricating grease can remain suspended indefinitely, and will result in abrasion of bearings and moving surfaces.

The maintenance schedule will usually require periodic inspection and cleaning of the rotor and the stator windings. There are several methods by which this can be accomplished. Low pressure compressed air can be used to blow out the dirt and dust. However, in the case of the stator, this method can sometimes result in dirt being driven deeper into the windings. Instead, vacuum suction would be used in this instance. In fact, vacuum suction is always the preferred method for removing dust and dirt from stator windings, or from any other motor component when there would be the danger of compressed air forcing dirt and abrasive particles deeper into the mechanism. Accumulations of grease and oil can be removed with the proper type of petroleum solvent. In any case, you should consult local maintenance schedules and instructions for the specific and precise cleaning method required.

MAINTENANCE AND ALIGNMENT OF DRIVES.—The mechanism or linkage which transmits the motion and power of the prime mover to the driven equipment is referred to as the drive. Proper maintenance and operation of the drive is essential since its mechanical efficiency and alignment will directly affect the



ALLIS-CHALMERS FLEXIBLE COUPLING



METHOD OF ALIGNMENT

54.18

Figure 6-4. —Coupling.

performance of both the prime mover and the driven equipment. Two fairly common types of drives used with electric motors are the flexible coupling and the belt drive.

The coupling shown in figure 6-4 connects or couples the shaft of the prime mover to the shaft of the driven equipment. The coupling is designed to permit very slight misalignment between the two shafts. This flexibility will also permit the coupling to absorb some of the torque or twisting force which results from the inertia of the driven equipment when the motor is started and brought up to speed. However, any misalignment in excess of these small tolerances will result in rapid wear of the coupling hubs and bushing pins, vibration of the shafts, and of course, a reduction in the transmission of power from the prime mover. Vibration will be transmitted through the shafts to moving or rotating parts of both the electric motor and the driven equipment. This inevitably results in excessive wear of the various bearings which support the moving or rotating parts, which in turn results in more misalignment, vibration, and wear. The point is that small vibrations, which at first may seem insignificant, can eventually develop into major casualties and breakdowns.

While the motor is in operation, check the coupling for any unusual noise or vibration. At prescribed intervals, maintenance schedules will also require the operator to check the alignment of the coupling with a straightedge, dial indicator, thickness gage, or wedge, and realign the coupling as necessary. For detailed instructions relating to the realignment procedure, consult the manufacturer's instructions.

Various belt and pulley arrangements are also used as drives on electric motors. These belt drives are somewhat similar to the fan belt arrangements which drive the fan, water pump, and generator on automobiles. The belt, which can be made either of rubber or leather, rides on grooved pulleys or sheaves; one sheave being connected to the shaft of the prime mover and the other sheave being connected to the shaft of the driven equipment. In this way, the rotation of the electric motor is transmitted to the shaft of the driven equipment.

Perhaps one of the most important aspects of belt drive maintenance is proper belt tension. If the belt is too loose or slack, the power of the prime mover will not be transmitted efficiently. Belt slippage will also result in excessive rubbing and wear of the belt on the sheaves. Sheaves that are worn or out of alignment can also contribute to excessive belt wear. In addition, belt slippage can be caused by oil or grease which is allowed to accumulate on the sheaves. If the belt is too tight, on the other hand, the stress will be transmitted to the bearings in the sheaves and along the shafts. This, of course, will result in excessive bearing wear and misalignment.

A properly adjusted belt will have a very slight bow in the slack side when running. When idle, the belt should have an alive springiness when thumped with the hand. Lack of this springiness will indicate too little tension. A belt which is too tight will feel dead when thumped.

While the motor is in operation, you must visually inspect the belt drive periodically for any indication of improper tension or slippage. Be careful, also, to keep the belt and sheaves clean and free of grease or oil at all times. At prescribed intervals, you will also be required to inspect the belt for fraying, cracks, or other indication of unusual wear. The sheaves must likewise be inspected and their alignment checked. Excessive belt rubbing on the sheaves indicates belt slippage. Sheaves which are out of alignment can be caused by excessive belt tension.

Occasionally, it may be necessary to replace a worn and frayed belt. If the drive has multiple belts, ALL the belts must be replaced with a set of matched belts. The belts in a matched set are machine-checked to ensure equal size and tension.

In addition to the maintenance and inspections outlined above, the operator will also be required to test and inspect various other items related to the motor, such as control switchboards, pilot lamps, alarms, and circuit breakers. Electrical connections and conductors must also be periodically inspected for proper insulation and security.

Finally, a brief word should be said about safety. A great deal can be written, and has been written (see the latest edition of Basic Electricity) concerning safety precautions and procedures relating to the operation and maintenance of electrical equipment. In operating electric motors, and in performing operator maintenance on electric motors, it would be well to remember that you are working on a device which carries a force of energy that is not only useful but also deadly.

INTERNAL COMBUSTION ENGINES

An internal combustion engine is a machine that produces mechanical energy by burning fuel within a confined space (the engine cylinder). The term applies to both diesel and gasoline engines.

While the Utilitiesman does not have to be a mechanic, he should have a knowledge of the basic principles underlying diesel and gasoline engine operation. This is important since the Utilitiesman has to operate and maintain the engine used to drive various types of mechanical equipment, such as pumps and compressors.

Diesel Engines

Diesel engines change heat energy into mechanical energy. Heat is developed when a mixture of compressed fuel and air burns inside a cylinder. Expanding gases are formed. The gases exert a pressure on a PISTON which is connected to a CRANKSHAFT by means of a CONNECTING ROD. The straight-line movement of the piston is changed to a rotating movement of the crankshaft.

FOUR-STROKE CYCLE DIESEL.—There are four-cycle and two-cycle diesel engines. In a FOUR-)YCLE engine, each cylinder imparts one power impulse to the shaft every fourth stroke of the piston, or every second revolution of the crankshaft. A two-cycle engine imparts one power impulse to the crankshaft per cylinder for every second stroke of the piston, or one power impulse per revolution of the crankshaft. First, we will discuss the principle of operation of the four-stroke cycle.

The following series of events take place in the four-stroke cycle engine: (1) inlet or intake stroke; (2) compression stroke; (3) combustion or power stroke; and (4) exhaust stroke. Four strokes of the piston, or two complete revolutions of the crankshaft, are necessary to complete the cycle.

Figure 6-5 illustrates the four-stroke cycle in a diesel engine. In view A the crankshaft is forced to turn in the direction of the arrow and pulls the piston down, The inlet valve opens and a charge of air is admitted into the cylinder. This is called the INLET (or INTAKE) STROKE.

Now, note in view B that the piston is moving upward and the inlet valve is closed. As the piston moves upward it compresses the air into a smaller and smaller space. The decrease in volume causes an increase in pressure and a corresponding increase in temperature. Fuel oil is sprayed under high pressure into the combustion chamber just before the piston reaches the top of its stroke. The fuel ignites readily on coming into contact with the compressed air in the combustion chamber. This is called the COMPRESSION STROKE. In case the reason for ignition is not clear, we might point out that all fuels have a certain temperature at which they will ignite. The temperature of the compressed air in the combustion chamber is well above that required for ignition of the fuel oil. Thus, the finely atomized spray of fuel oil ignites easily.

As indicated in view C, the burning fuel and air mixture expands rapidly and the piston is forced downward. Heat energy is changed to mechanical energy and the crankshaft is forced to rotate. Here you have the POWER STROKE.

In view D, the piston has completed the power stroke. As it starts upward the exhaust valve opens and the burned gases are pushed out of

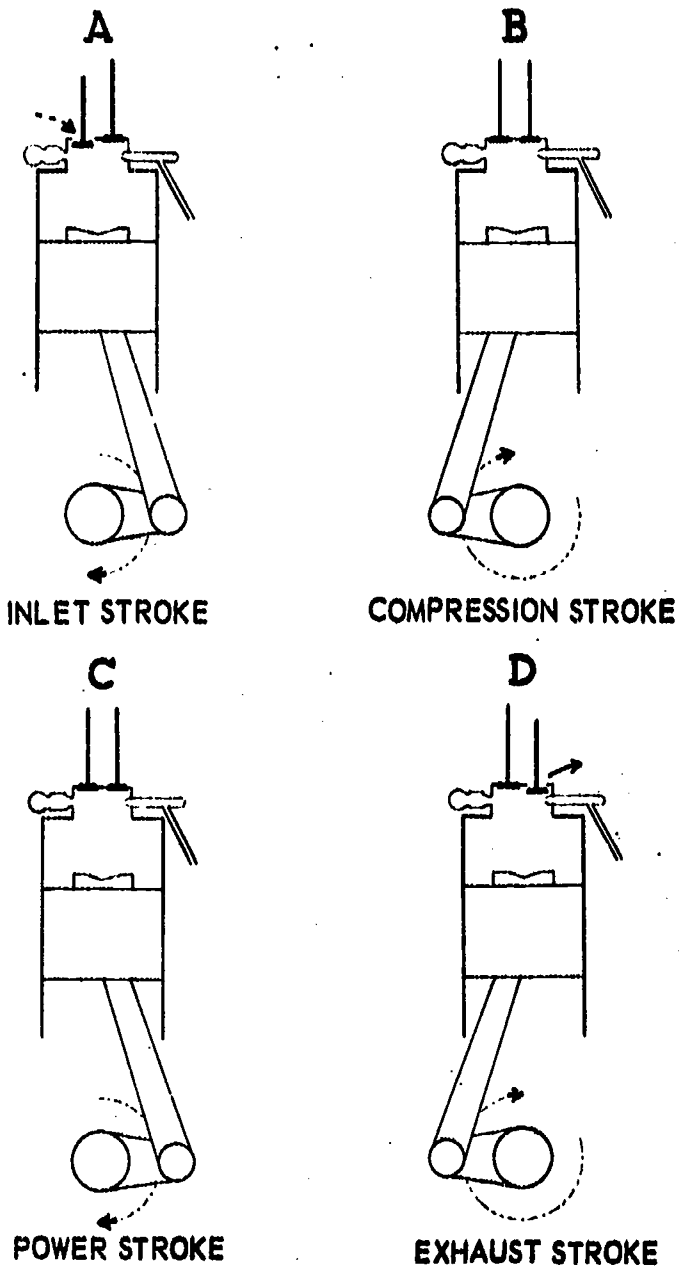


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Figure 6-5. — Four-stroke cycle.

the cylinder. This is the EXHAUST STROKE, and completes the four-stroke cycle.

Of course, you usually have more than one cylinder in a diesel engine. The pistons are arranged on the crankshaft in a definite pattern. Thus, at any instant, each piston is in some phase of the four-stroke cycle. The result is a smooth delivery of power to the crankshaft.

TWO-STROKE CYCLE DIESEL. — The two-stroke cycle engine requires two strokes or one revolution of the crankshaft, while the four-stroke cycle requires two revolutions of the crankshaft to complete a cycle.

For a run-down on how the two-stroke cycle operates, first note that view A, figure 6-6 illustrates a two-stroke cycle cylinder filled with a charge of air. The piston has started to move upward on the compression stroke and the exhaust valve is closed. The air in the cylinder is compressed and as the piston approaches the top of its stroke, fuel oil is injected into the combustion chamber. The fuel oil is under high pressure and forms a mixture that is easily ignited by the high temperature of the air in the cylinder.

The fuel burns and the expanding hot gases force the piston down on the POWER STROKE (see view B, fig. 6-6). As the piston nears the end of the power stroke the exhaust valve opens and the gases are released to the atmosphere (see view C, fig. 6-6). The piston continues to move downward on the power stroke, uncovering scavenging air ports through which air under supercharged pressure is forced into the cylinder. (See view D, fig. 6-6.) This air is provided by a high-speed blower, which usually is engine-driven. The air forces out any remaining burned gases and supplies a fresh charge of air for the compression part of the next stroke. This operation, called SCAVENGING, is peculiar to the two-stroke cycle engine.

OPERATION AND MAINTENANCE OF DIESEL ENGINES. — To keep diesel engines in peak operating condition, the operator must give careful attention to the following factors: prestart inspection, starting the diesel, securing the diesel, and operator maintenance. Items to be covered in each of these phases of engine operation and maintenance follow.

Prestart Inspection. — Before a diesel can be started, the operator must perform a prestart inspection to ensure that the engine is ready for operation. The specific inspection routine may vary somewhat according to each particular engine installation. The basic procedure, however, will require the operator to inspect for a sufficient supply of fuel oil, lube oil, and cooling water. The operator must also be alert for any leakage of these fluids. When replenishment of cooling water is necessary for the radiator, use clean or soft water so as to keep the engine water jackets and coolant circulating system free of sediment. If the engine is still hot from previous operation,

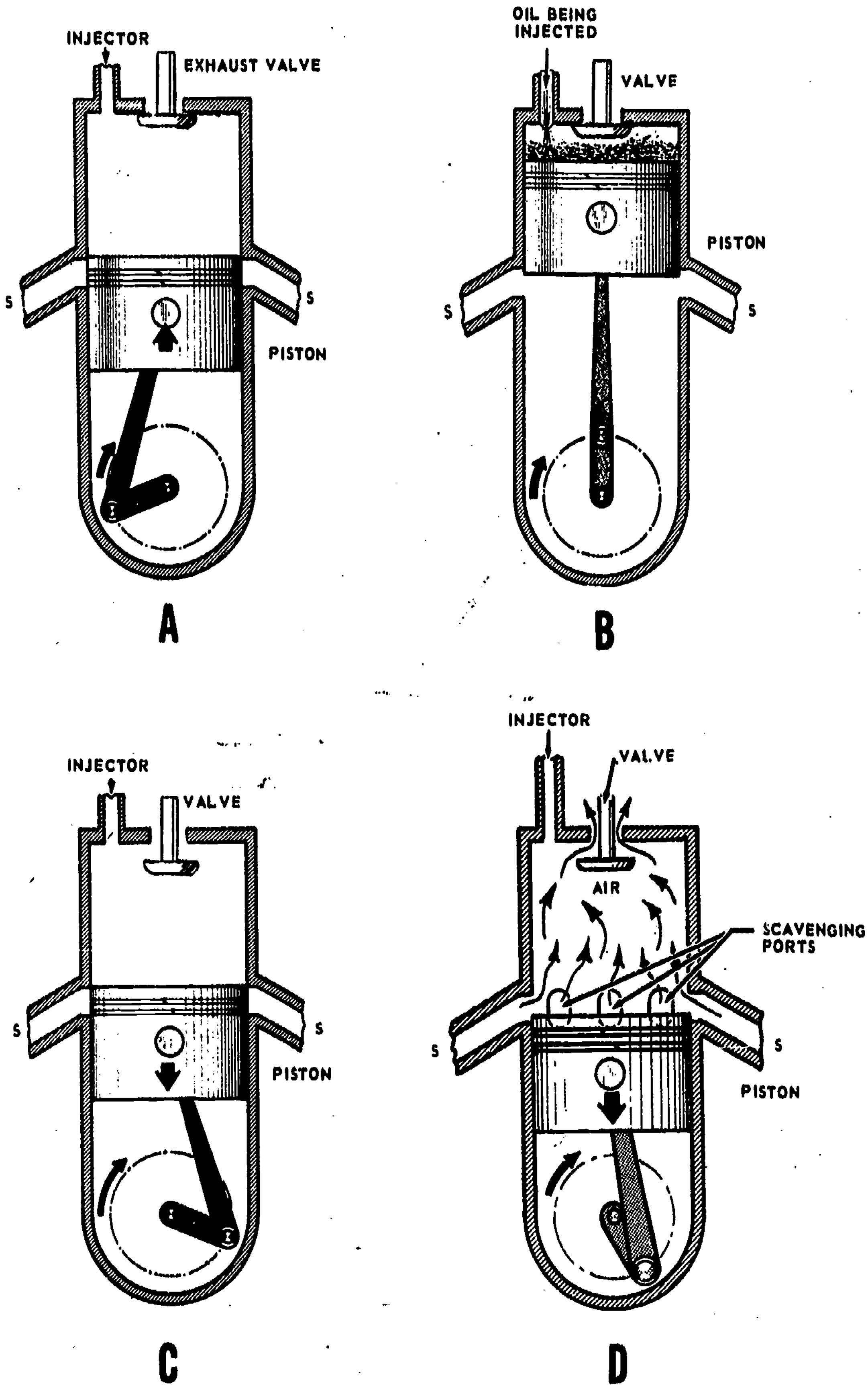

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Figure 6-6.—Two-stroke cycle: (A) Compression stroke, (B) Power stroke, (C) Near end of power stroke, (D) Scavenging.

care must be taken not to add large amounts of cold water. Sudden cooling can crack cylinders and cylinder heads, and will cause unequal contraction of the structural and working parts which can lead to seizing of pistons. When topping-off batteries, use distilled water.

Accessories and drives must be inspected for loose connections and mountings. If the diesel starting system is battery-equipped, check the batteries for cracks and leaks, and ensure that the battery cables and vent caps are clean and secure. Prior to starting, fire extinguishers must also be inspected for ease of removal, full charge, and security and cleanliness of valves and nozzles.

Starting the Diesel.—Diesel engines must rely on some external source of power for starting purposes. The starting mechanism may be an electric motor, an auxiliary gasoline engine, compressed air, or even a hand cranking mechanism. Whatever system is used, the starter's purpose is to force the pistons to reciprocate and compress air drawn into the cylinders. When sufficient compression has been developed with the aid of the starter, the temperature of the air in the cylinders will be high enough to ignite the injected diesel fuel. Thus, internal combustion takes place and the engine begins to crank under its own power. Once the engine has been started, the operator must immediately observe the following procedures.

1. Throttle the engine to normal (fast idle) warm-up speed. The diesel should not be permitted to slow idle for any appreciable length of time since, under these conditions, the engine-driven blower delivers an insufficient amount of air for complete combustion. This results in partially burned fuel oil forming heavy carbon deposits which foul valves, piston rings, and the exhaust system.

2. Immediately check the lube oil pressure gage. If the gage does not indicate positive and sufficient lube oil pressure within 30 seconds, stop the engine immediately and report the difficulty to proper authority.

3. Observe the temperature gage during the warm-up period. The engine must not be placed under load until it reaches the proper warm-up temperature. Placing a cold engine under full load may result in serious damage to the engine due to poor lubrication at low temperature and uneven rates of expansion.

While the engine is in operation, other inspections and checks will be required. Usually, this will involve checking of lube oil and fuel oil levels, filters and strainers, accessories and drives, and engine operating temperatures and pressures. Normally, the operator will record the results of these inspections in an operating log.

Securing the Diesel.—If the engine installation permits, it is desirable to let the engine fast idle without load for a short time before stopping. This allows for a gradual reduction of engine temperature. Once the diesel has been shut down, the stand-by lube oil pump should be kept in operation for a short time. This will allow the lube oil to further cool the engine. The cooling water should also be kept circulating for 15 to 30 minutes in order to bring the working parts to a low temperature without danger of distortion from one part cooling faster than another.

While the engine is cooling, the operator must perform various other checks to determine the need for adjustment, repair, and replacement or renewal of parts as necessary. Some of the items that might be included in this inspection follow:

1. Check fuel, oil, and water as in the prestart inspection.

2. Check engine instruments or gages for proper readings.

3. Check accessories and drives as in the prestart inspection.

4. Inspect air cleaners and breather caps.

5. Inspect fuel filters.

6. Inspect engine controls and linkage.

7. Inspect the batteries as in the prestart inspection.

8. Inspect all electrical wiring for condition of insulation and security of connections.

Operator Maintenance.—According to the prescribed maintenance schedules, the engine operator will perform other inspections and maintenance duties in addition to those already outlined. These maintenance routines will occur at various intervals, some weekly, some monthly, some quarterly, and so on. The items listed here will give you some idea of what the maintenance schedules can entail.

1. Disassembly and cleaning of air filters and breather caps.
2. Removal and cleaning of oil filter elements.
3. Inspection of fuel lines, fuel filters, and fuel pump.
4. Cleaning of battery casings and terminal posts; checks for proper electrolyte level and specific gravity.
5. Inspection, cleaning, and lubrication of generator; inspection and test of voltage and current regulator.
6. Inspection and lubrication of starting mechanism.
7. Inspection of radiator; inspection of water pump, fan, and drive belts.
8. Inspection of crankcase, valve covers, timing gears, and clutch housing.
9. Inspection of cylinder heads and gaskets.

Gasoline Engines

Like the diesel engine, the gasoline engine changes heat energy into mechanical energy. The physical construction of the gasoline engine is very much the same as that of the diesel. There are pistons, cylinders, valves, connecting rods, a crankshaft, and an engine block in each. There is also a cooling system to carry the heat away, a lubrication system to reduce the friction of moving parts, an air system to supply air for combustion in the cylinders, and fuel system to supply fuel.

Most gasoline engines operate on the four-stroke cycle. The difference between gasoline and diesel engine operation is (1) the method of introducing the fuel and air into the cylinders and (2) the means by which the compressed fuel and air are ignited in the cylinders.

In a diesel engine the air is admitted to the cylinder on the intake stroke of the piston. The fuel oil is sprayed into the chamber AFTER the air has been compressed. In the gasoline engine the fuel (gasoline) and air are mixed together BEFORE being admitted to the cylinder. The intake stroke of the piston sucks air through the air cleaner into the carburetor. In the carburetor the clean air is mixed with gasoline (vaporized) from the fuel tank. The air and gas mixture continue on to the intake manifold, which is connected to the cylinder head. An intake valve admits the air-gas mixture into the cylinder.

The diesel engine produces combustion by using the heat of compression. In the gasoline engine, an electric SPARK is provided by the spark plug to ignite the air-gas mixture. Ignition occurs as the piston completes its compression stroke. The ignited gases expand and the piston is pushed down on the power stroke. The exhaust stroke of the piston forces the burned gases out of the cylinder chamber.

OPERATION AND MAINTENANCE OF GASOLINE ENGINE. — The operating procedures and operator maintenance routines for gasoline engines are essentially the same as those for diesel engines. Aside from the fundamental difference in the ignition process, STARTING procedures for gasoline engines are much the same as for diesels. There is, however, one important exception. Most gasoline engines are equipped with priming or choking devices which aid in starting a cold engine. Generally, these priming devices simply dump raw fuel into the cylinders; that is, the fuel is not thoroughly mixed with air or atomized prior to induction into the cylinders. Although such a rich mixture of fuel aids in achieving initial combustion, not all the fuel is burned. In other words, we have incomplete combustion. Prolonged or excessive choking during and after the start can, therefore, lead to carbon deposits being built up in the engine. For this reason, the operator should always use care and restraint in choking or priming the engine, both during and after the start.

SECURING procedures for gasoline engines are also basically the same as for diesels, although some gasoline engine installations may not permit circulation of lube oil and coolant after the engine has been stopped.

As you might expect, OPERATOR MAINTENANCE routines for gasoline engines differ from those for diesels in accordance with the slight differences in design and construction of gasoline engines. In other words, gasoline engine maintenance and inspection schedules must provide for the inspection, adjustment, and maintenance of such items as carburetors, chokes, ignition coils and wiring, distributors, and spark plugs.

SAFETY

Whenever gasoline or diesel engines have been secured for maintenance and inspection purposes, the operator must always guard against intentional or inadvertent starting of the engine by uninformed personnel. This rule, of course, applies to all types of prime movers, electric motors included. It also applies equally as well to maintenance and inspection operations being performed only on the driven equipment. Regardless of whether or not the work is being done on the prime mover itself or on the driven equipment alone, unintentional starting of the prime mover during the maintenance operation can result in serious damage to machinery and serious injury to maintenance personnel. For this reason, prime mover controls must always have warning placards or posters securely attached and plainly visible before the maintenance and inspection operation is begun. In some situations, it may be a good idea to completely disable the starting mechanism (see LOCKOUT DEVICES, chapter 16) so that even if personnel fail to see or read the warning placards, the prime mover cannot possibly be started.

During the maintenance operation, the operator must keep a strict accounting of all tools and parts. Tools, nuts and bolts, or any other material left adrift, may foul a moving part and completely disable the machinery during subsequent operation. There is another reason for keeping a strict accounting of parts whenever components are disassembled. Parts that work together wear together. The various parts of valve assemblies, bearing assemblies, and so on, should, therefore, be carefully marked and grouped during disassembly and replaced in the same position from which they were removed. Otherwise, discrepancies in fit and joining can result which may reduce the mechanical efficiency of the moving parts and may eventually lead to a breakdown.

Whenever an inspection routine is being accomplished on an engine or motor that is in operation, the operator must use particular caution while working near moving parts. Loose clothing, rags hanging from pockets, dangling key chains, etc., can easily become entangled with, or drawn into, moving parts and a serious accident can occur.

CLEANLINESS

The importance of cleanliness with respect to engine maintenance and inspection cannot be overemphasized. Dirt which is allowed to accumulate on and around an engine will inevitably find its way to the inside of that engine. It may be carried into the engine with air, fuel, lube oil, or water, or it may be introduced by a careless workman. Dirt can cause sludge and scale deposits which impair circulation of fuel, oil, and water, and abrade moving parts. Large accumulations of dirt on external surfaces can, in some instances, serve to insulate the surface and reduce cooling.

Normally, there will be specific instructions available locally which have to do with cleanliness precautions while handling fuel, lube oil, etc. You must know and observe these precautions without fail. A few of the most fundamental cleanliness precautions follow:

1. Never use waste or linty rags around fuel or lube oil containers, fuel inspection equipment, or carburetors.
2. Keep all fuel and lube oil handling equipment—such as measures, funnels, and containers—scrupulously clean and covered when not in use.
3. Use clean, soft water in engine radiators and coolant systems in order to keep the engine water jackets free of sediment; use distilled water in topping-off batteries.
4. Keep engine air intake filters clean in order to maintain sufficient induction of air.

PUMPS

Simply defined, a pump is a device which uses an external source of mechanical power (prime mover) to move liquid from one point to another. To accomplish this, the pump may employ a pushing, pulling, or throwing motion, or a combination of these effects. In this connection, pumps are often named or classified according to the type of movement that causes the pumping action: diaphragm, rotary, centrifugal, or airlift, for example.

Regardless of its design or classification, every pump has a power end and a liquid end. The POWER END is some form of prime mover, such as an electric motor, internal combustion engine, steam turbine, etc. In steam driven pumps, the power end is often referred to as the steam end. The basic purpose of the power end is to develop the mechanical motion or force required by the liquid end.

The LIQUID END is that part or portion of the pump where the mechanical motion or force developed by the prime mover is actually exerted on the liquid. This part of the pump must have provisions for suction (where the liquid enters) and for discharge (where the liquid leaves the pump). The liquid end is most often referred to as the pump end; although it may also be called the water end, oil end, and so on, to indicate the nature of the substance being pumped.

Finally, every pump must be equipped with devices for controlling the direction of flow, the volume of flow, and the operating pressure of the pump. A device which performs one or more of these control functions is called a VALVE. A valve which permits liquid flow in one direction only is classified as a CHECK VALVE. In most cases, check valves open and close automatically; that is, they are kept closed or seated by spring tension or the force of gravity until the liquid pressure above or below the valve overcomes the spring or gravity resistance and causes the valve to open. Check valves of this type are used in centrifugal pumps to automatically control the suction and discharge of liquid in the pump end at the proper time. Figure 6-7 shows a vertical check valve. In this case, the valve is kept seated by its own weight or the force of gravity (but it could also be kept closed by a spring, if desired).

Another type of valve found in pump systems is the STOP VALVE. Stop valves are usually opened or closed manually by means of a handwheel. They are used primarily to start or stop the flow of liquid through the pump during certain phases of operation. Thus, stop valves are often placed on suction and discharge lines so that the pump may be isolated or sealed off from the rest of the liquid system. Figure 6-8 illustrates the operation of a gate valve which is a type of stop valve. A gate or wedge is raised or lowered by turning the handwheel. Some types of stop valves are used for throttling purposes; that is, to regulate the flow of liquid. Gate valves, however, are never recommended for throttling service since the flow of liquid past the partially opened gate can rapidly corrode the gate face. Instead, the gate can be replaced with a tapered needle valve (another type of stop valve) which gradually opens or closes through the valve seat.

A third type of valve generally found on most types of pumps is the RELIEF VALVE. As you can see from figure 6-9, most relief valves are quite similar in their design to check valves. These valves are designed to open when the liquid pressure in the pump becomes dangerously high. In most cases, the outlet of the relief valve is connected to a recirculating line which passes the excess liquid back to the suction side of the pump. Almost all pressure relief valves will be fitted with an adjusting nut or screw which permits the spring tension to be regulated. In this way, the pressure at which the valve will open may be varied.

As a Utilitiesman, you will probably work with many types of pumps, large and small. For instance, pumps are used to supply feed water to boilers; to deliver fuel oil to oil-fired boilers; to circulate coolants and lubricants in

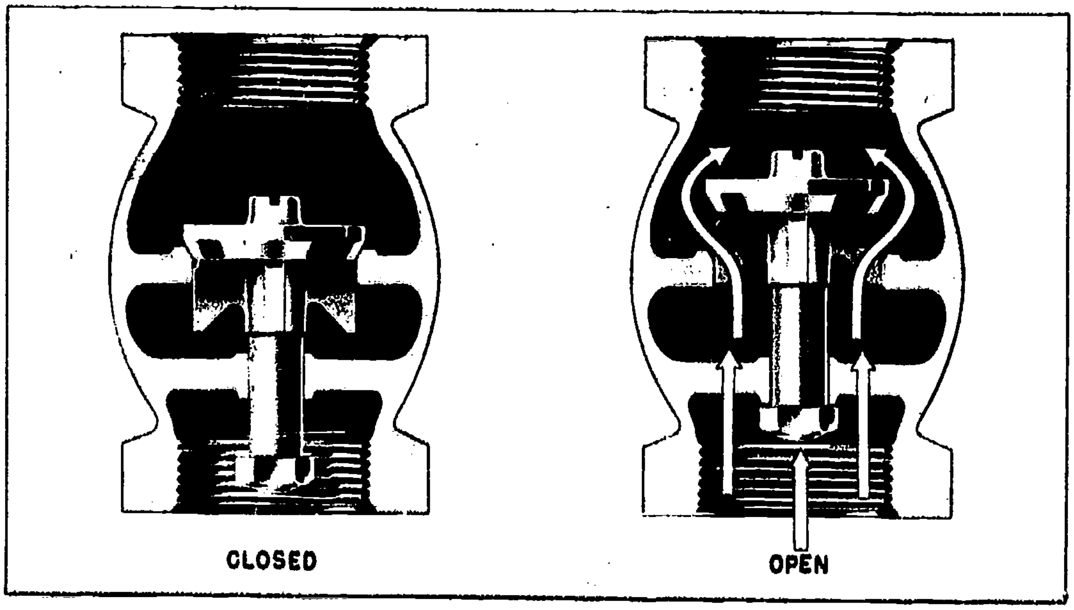

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Figure 6-7. — Vertical check valve.

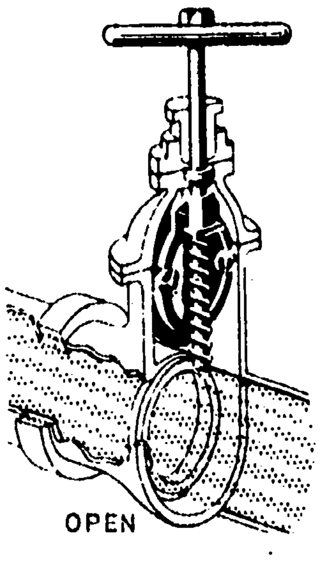

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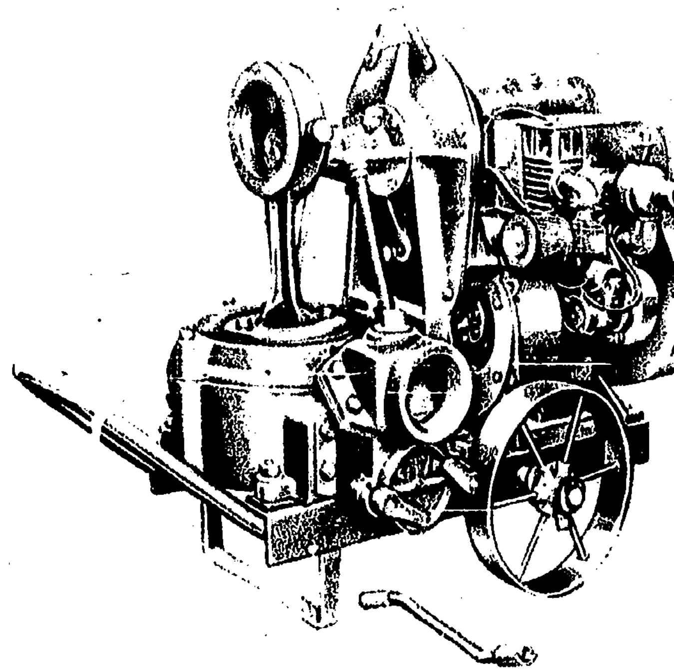
Figure 6-8. —Operation of gate valve.

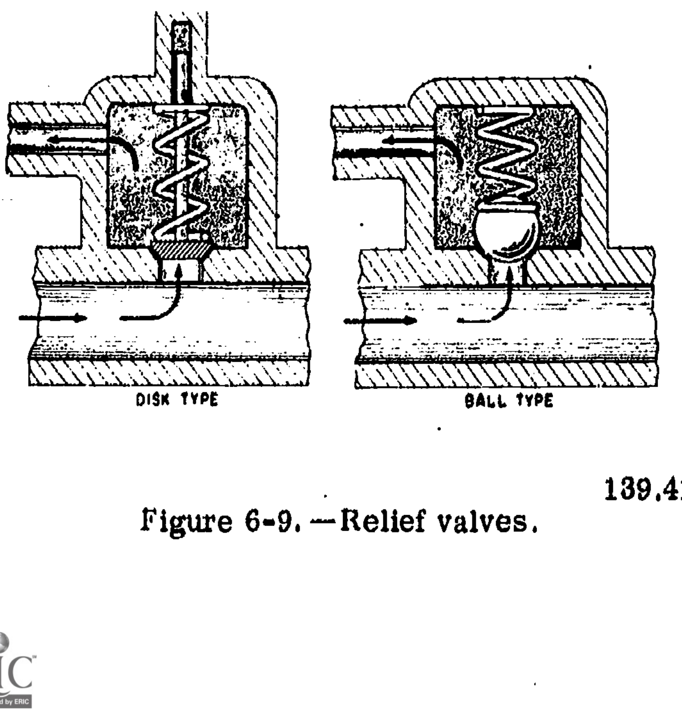


54.21
Figure 6-10. —Portable diaphragm pump.

internal combustion engines; to supply chemical feed in water purification systems; to lift water from wells and distribute it throughout a system; and to discharge sewage into settling tanks or mains. For the purposes of our discussion, we will deal with five broad categories of pumps: diaphragm pumps, rotary pumps, centrifugal pumps, airlift pumps, and jet pumps.

DIAPHRAGM PUMPS

Diaphragm pumps (fig. 6-10) employ a flexible diaphragm to move the liquid. The prime mover is usually a small gasoline engine with an eccentric connecting rod arrangement which converts rotary motion to reciprocating motion. On the suction stroke, the diaphragm is drawn upward into a concave configuration. This movement of the diaphragm results in a partial vacuum which causes the suction ball valve to unseat (and at the same time keeps the discharge ball valve seated) and admit liquid to the pump cylinder. On the discharge stroke, the diaphragm is pushed downward, forcing the trapped liquid out through the discharge valve. Thus, the liquid is made to move by the reciprocating motion of a flexible diaphragm.



139.41
Figure 6-9. —Relief valves.

Since the diaphragm forms a relatively perfect seal in the pump cylinder, between the liquid being pumped, and the rest of the pump and driving mechanism, there is little danger of liquid abrasion or corrosion of moving parts behind the diaphragm. For this reason, diaphragm pumps are especially well suited for pumping mud, slime, silt, and other wastes or heavy liquids containing debris such as sticks, stones, or rags. Liquid strainers are, however, fitted at the suction inlet to prevent large objects from fouling the suction and discharge valves or possibly damaging the diaphragm.

You may have occasion to use the diaphragm pump for such duties as dewatering trenches where sewerlines or waterlines are to be laid, or when repairing breaks in waterlines or sewerlines.

Two of the most popular types of diaphragm pumps are the mud hog (closed discharge) and the water hog (open discharge). The MUD HOG is suitable for jobs that require pumping heavy and thick liquids which must be discharged at a distance away from the pump. The pump is fitted with discharge hose connections, and the ball valves and chambers are designed to prevent fouling by sticks, stones, rags, and so on.

The WATER HOG, on the other hand, is used for pumping thinner and less viscous liquids. It can, nevertheless, handle liquids containing sand, gravel, mud, etc. The discharge outlet from the water hog is open to permit free flow and increased discharge capacity. Thus, the liquid is discharged directly at the pump. A discharge hose, however, can be fitted to the pump if desired, but this will reduce its efficiency somewhat. Both the water hog and mud hog can be of either the simplex or duplex type.

Due to the nature of the liquids handled by diaphragm pumps, operator inspection during pump operation becomes particularly important. It will be necessary to make frequent inspections of the suction inlet strainer in order to avoid accumulations of debris which reduce suction efficiency. Most diaphragm pump installations also permit easy access to the suction and discharge ball valves. The valve mechanisms then can be inspected frequently in order to detect scoring, fouling, and improper valve seating.

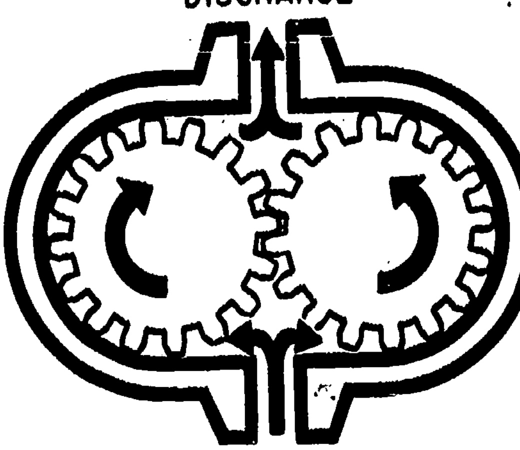
Because the diaphragm and ball check valves are subjected to the corrosive action of sand, gravel, etc., it is natural to expect that they will require the most frequent attention. Operator maintenance schedules will, therefore, stress a continuing program of inspection and cleaning of these parts. In most cases, it is not practicable to repair damaged or worn diaphragms and valves. Rather, the worn or damaged parts are simply replaced with new ones. For this reason, it would be wise to keep an adequate supply of these parts readily available.

ROTARY PUMPS

All rotary pumps employ the principle of entrapment and displacement of fluid by rotating elements of various design. These rotating parts, which may be gear teeth, screws, lobes, vanes, etc., trap the fluid at the suction inlet and remove it to the discharge outlet. Instead of "throwing" the water as in a centrifugal pump, a rotary pump traps it, pushes it around inside a closed casing, and discharges it in a continous flow. Since rotary pumps move liquid according to this method, they are often classified under the broad heading of positive displacement pumps.

The simplest type of rotary pump is the GEAR PUMP, shown in figure 6-11. This type of pump employs two spur gears which rotate in opposite directions and mesh together at the center of the pump. One of the gears is coupled to the prime mover (usually an electric motor) and is called the driving gear. The other gear, which receives its motion by meshing with the driving gear, is called the driven gear. It is important to note that the actual movement of liquid is accomplished as the gear teeth rotate against the casing of the pump, thereby trapping the liquid and pushing it around to the discharge outlet. The meshing together of the two gears does not in itself move or pump liquid. Much rather, the meshing of the gear teeth, in effect, forms a constant seal between the suction and discharge sides of the pump and thus prevents liquid from leaking back toward the suction inlet.

Very small clearances are permitted between the meshing gears, and between the gear teeth and pump casing, in order to avoid unnecessary friction. This also allows the liquid being handled to act as a lubricant for the rotating parts. It should be evident, however, that if excessive clearances are allowed to develop between the gear teeth and casing, or between



38.108

Figure 6-11.—Gear-type rotary pump.

the gears where they mesh, then the efficiency of the pump will be considerably reduced. For this reason, rotary pumps are rarely, if ever, used to handle corrosive or abrasive liquids.

Most rotary pumps have stuffing boxes provided at the rotor shafts to prevent excessive leakage at the shaft joint. In addition, various types of bearings may be fitted at the ends of the rotor shaft to minimize friction.

There are many different types of rotary pumps; the classification generally being made according to the type of rotating element employed. Whatever form of rotating element is used, the basic principles of pump operation remain the same.

Generally, rotary pumps are considered to be self-priming; that is, the pump end need not be filled with liquid in order to initiate pumping action. Instead, the movement of the rotating elements will create a partial vacuum sufficient to lift or draw liquid into the pump and initiate the pumping process. It should be noted that self-priming and good suction lift are actually characteristics of the whole class of positive displacement pumps.

Rotary pumps have the added advantage of being less expensive and considerably simpler in their construction. In the utilities field, rotary pumps may be used for fuel oil pumping in boiler houses, for pumping chemical feed in water purification systems, for priming larger pumps, and for special applications such as emergency pumps at firefighting stations.

OPERATION AND MAINTENANCE OF ROTARY PUMPS

The rotary pump is susceptible to hydraulicking. The discharge stop valve must, therefore, be in the open position before the pump is started. In addition, it is considered good operating practice to prime these pumps prior to operation whenever possible, and particularly if the pump has been standing idle for any length of time. This is true in spite of the fact that rotary pumps are self-priming. The reason should be obvious if you remember that the rotating elements of these pumps are lubricated by the liquid handled in the pump. If the pump end is filled with fluid prior to starting, then unnecessary friction and wear of the rotating elements is avoided.

As you might expect, great attention is given in rotary pump maintenance schedules to preserving the proper clearances between rotating parts. Thus, there will be periodic checks for slippage. In addition, when the pump is dismantled, the actual clearances should be carefully measured and compared with the manufacturer's specifications.

CENTRIFUGAL PUMPS

When a body, or a liquid, is made to revolve or whirl around a point, a force is created which impels that body or fluid to move outward from the center of rotation. This phenomenon is called CENTRIFUGAL FORCE, and it is from this force that the centrifugal pump takes its name.

The basic centrifugal pump has only one moving part: a wheel or impeller which is connected to the drive shaft of a prime mover and which rotates within the pump casing. The design or form of the impeller may vary somewhat. However, whatever its form, the impeller is designed to impart a whirling or revolving motion to the liquid in the pump. When the impeller rotates at relatively high speeds, sufficient centrifugal force is developed to throw the liquid outward and away from the center of rotation. Thus, the liquid is sucked in at the center or eye of the impeller (center of rotation) and discharged at the outer rim of the impeller.

It is important to note that by the time the liquid leaves the impeller, it has acquired considerable velocity. In this connection, there is a fundamental law of fluid physics which states, in part, that as the velocity of a fluid increases, the pressure or pressure head of that fluid decreases. We can, therefore, characterize the liquid discharge from the impeller as having a high velocity but low pressure.

Before the liquid can be discharged from the pump, however, some means must be found to INCREASE the pressure. In other words, the primary concern in practically all pumping systems is that the discharge pressure be maintained so that liquid can be distributed effectively throughout the system. In the case of centrifugal pumps, what is needed is some device which will decrease the velocity of the impeller discharge and thereby increase the liquid pressure at the discharge outlet.

In the VOLUTE type centrifugal pump, shown in figure 6-12, the impeller discharges into a volute or gradually widening channel in the pump casing. As the liquid passes into the expanding neck of the volute, its velocity is considerably diminished; and, with this decrease in velocity, there is an increase in pressure.

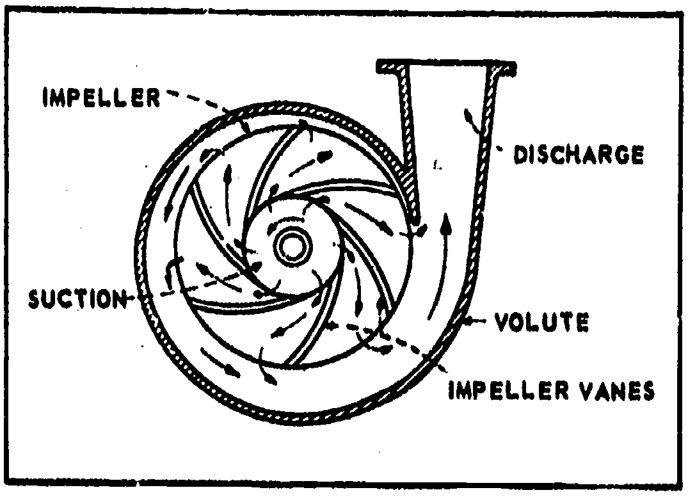


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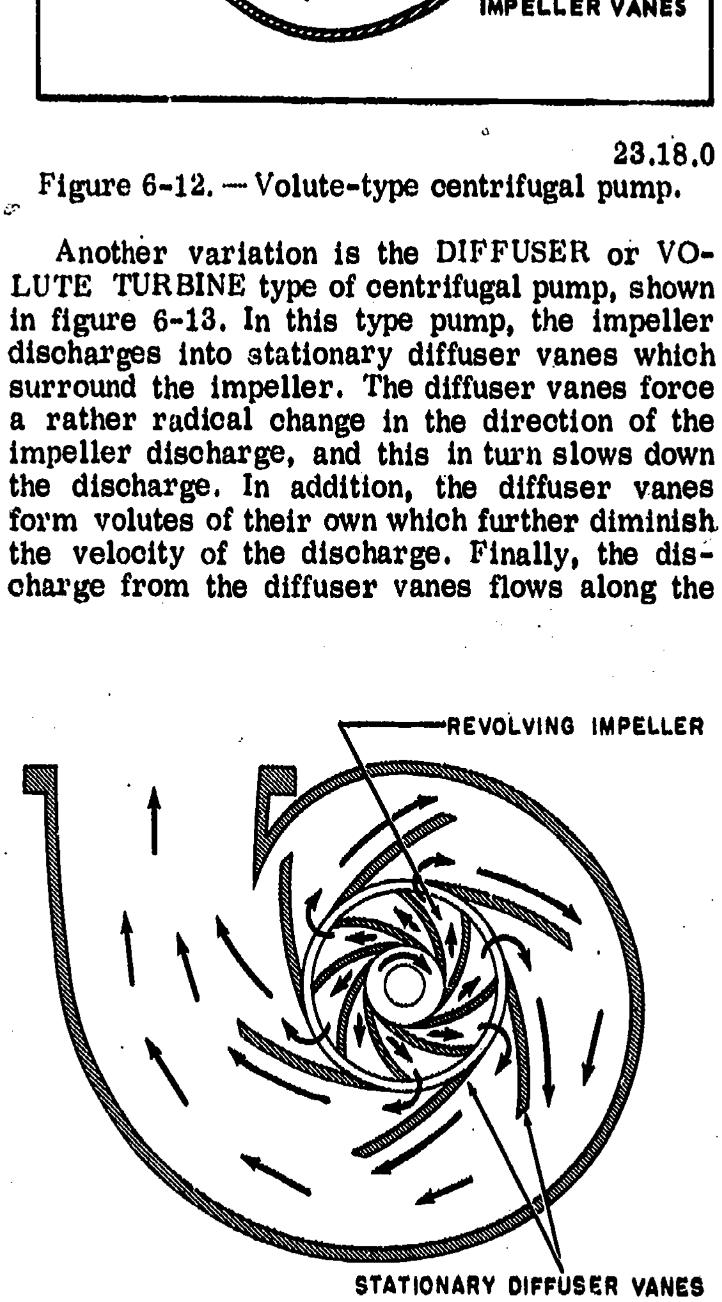
Figure 6-12. — Volute-type centrifugal pump.

Another variation is the DIFFUSER or VOLUTE TURBINE type of centrifugal pump, shown in figure 6-13. In this type pump, the impeller discharges into stationary diffuser vanes which surround the impeller. The diffuser vanes force a rather radical change in the direction of the impeller discharge, and this in turn slows down the discharge. In addition, the diffuser vanes form volutes of their own which further diminish the velocity of the discharge. Finally, the discharge from the diffuser vanes flows along the



23.19
Figure 6-13. — Diffuser-type centrifugal pump.

pump casing which, like the simple volute type pump, is also in the form of a volute. Thus, the diffuser type pump provides for a nearly complete decrease in velocity and consequent increase in discharge pressure.

Another method of increasing the discharge pressure of centrifugal pumps is by providing additional impellers. Pumps having only one impeller are classified as SINGLE-STAGE. Pumps with two or more impellers are referred to as MULTISTAGE. In multistage pumps, two or more impellers are placed on a common shaft (within the same pump housing), with the discharge of the first impeller being led into the suction of the next impeller, and so on. As the liquid passes from one stage to the next, additional pressure is imparted to it. In this fashion, the final discharge pressure of the pump can be increased considerably.

Generally, centrifugal pumps must operate at relatively high speeds in order to produce the necessary centrifugal force. Because of the high rotational speed of the impeller, its machine finish, or smoothness, and balance must be carefully preserved in order to minimize friction and avoid vibration. Close clearances must be maintained between the impeller HUB (the central portion of the impeller which fits around the shaft) and the pump casing in order to minimize liquid slippage between the discharge side of the pump casing and the suction side. Because of the high rotational speed of the impeller and the necessarily close clearances, the running surfaces of both the impeller hub and the casing at that point are subject to relatively rapid wear. To avoid renewing an entire impeller and pump casing solely because of wear in this location, centrifugal pumps are fitted with replaceable metal wearing rings. One ring (IMPELLER WEARING RING) is fitted on the hub of the impeller and rotates with it; a matching ring (CASING WEARING RING) is attached to the casing and is, therefore, stationary. These metal wearing rings perform essentially the same function as packing; that is, they seal a moving joint and, also, prevent excessive friction and wear. Like packing, the wearing rings are normally lubricated by the liquid handled in the pump. Also like packing, the rings must be replaced from time to time when they become worn in order to avoid excessive slippage or leakage.

The advantages of centrifugal pumps include simplicity, compactness, weight saving, and adaptability to high-speed prime movers. They have their widest application in water supply and distribution systems at shore facilities. Certain types of centrifugal pumps are also used for pumping sewage. These types, however, do not employ diffuser vanes since the rapid change in direction of the impeller discharge can cause suspended matter in the liquid to come out of suspension and form deposits which corrode and foul moving parts.

Other types of centrifugal pumps, known as turbine well pumps, are used to pump wells. In order to produce sufficient discharge pressure, these pumps are provided with multistage impeller arrangements, contained in volutes that are referred to as bowls. To ensure satisfactory suction, the impellers and bowls are set below the lowest drawdown or pumping level that the water in the well is expected to reach.

One of the disadvantages of centrifugal pumps is their relatively poor suction power. When the pump end is dry, the rotation of the impeller, even at high speeds, is simply not sufficient to lift liquid into the pump. The pump must, therefore, be primed before the pumping process can begin. For this reason, the suction lines and inlets of most centrifugal pumps are placed below the source level of the liquid pumped. The pump can then be primed by merely opening the suction stop valve and allowing the force of gravity to fill the pump with liquid. The static pressure of the liquid above the pump will, of course, also add to the suction pressure developed by the pump while it is in operation.

Another disadvantage of centrifugal pumps is that they are susceptible to the phenomenon known as CAVITATION. Cavitation will occur when the velocity of a liquid increases to the point where the consequent pressure drop reaches the pressure of vaporization of the liquid. When this happens, vapor pockets or bubbles form in the liquid and then later collapse when subjected to higher pressure at some other point in the flow. The collapse of the vapor bubbles can take place with considerable force. This effect, coupled with the rather corrosive action of the vapor bubbles moving at high speed, can severely pit and corrode impeller surfaces and sometimes even the pump casing. In extreme instances, cavitation has been known to cause structural failure of the impeller blades. Whenever cavitation occurs, it is frequently signaled by a clearly audible noise and vibration (caused by the violent collapse of vapor bubbles in the pump).

There are several conditions which can cause cavitation, not the least of which is improper design of the pump or pumping system. For example, if the suction pressure is abnormally low (caused perhaps by high suction lift or friction losses in the suction piping), the subsequent pressure drop across the impellers may be sufficient to reach the pressure of vaporization. A remedy in this case might be to alter the pump design by installing larger piping to reduce friction loss, or by installing a foot valve to reduce suction lift.

Cavitation may also be caused by improper operation of the pump. For instance, cavitation can occur when sudden and large demands for liquid are made upon the pump. As the liquid discharged from the pump is rapidly distributed and used downstream, a suction effect is created on the discharge side of the pump. One might think of it as a pulling action on the discharge side which serves to increase the velocity of the liquid flowing through the pump. Thus, as the pressure head on the discharge decreases, the velocity of the liquid flowing across the impellers increases to the point where cavitation takes place. Perhaps the easiest way to avoid this condition is by regulating the liquid demand. If this is not possible, then the only other practical alternative would be to increase the suction pressure by some means in order to maintain pressure in the pump under these conditions.

Operation and Maintenance of Centrifugal Pumps

The operating procedures and maintenance schedules for centrifugal pumps are generally similar to those of the other pumps we have discussed. Centrifugal pumps are also fitted with stuffing boxes and various types of bearings which, of course, will require periodic maintenance and inspection. Again, the reader is referred to manufacturer's instructions and locally prepared maintenance schedules for detailed operating and maintenance procedures.

There is, however, one particular operating practice common to nearly all types of centrifugal pumps which should be mentioned here. Unlike positive displacement pumps, the discharge stop valve on centrifugal pumps must be CLOSED prior to starting the pump. The reason for doing this is to allow the pump to work against the sealed discharge and build up an effective pressure head before attempting to move and distribute the liquid downstream. After the pump is up to speed, and the discharge valve is opened, the pump will continue to maintain that pressure head unless the operating conditions are otherwise altered. It should be noted that there will be no danger of hydraulicking while the pump is run with the discharge closed. If, in fact, the centrifugal pump were permitted to continue operation with the discharge sealed, it would simply build up toward its maximum discharge pressure and then begin to churn the liquid; that is, the discharge pressure would overcome the suction pressure and the liquid would continually slip back to the suction side of the pump. Nothing more would happen, except that the pump would build up heat since the liquid would not be able to carry away heat generated by the moving parts.

It should be admitted that there are several exceptions to the rule outlined above. For instance, if there are other pumps operating in parallel with the centrifugal pump, discharging into a common system, they will provide the centrifugal pump with an effective pressure head to start against. Another exception is the turbine well pump. This pump always has a pressure head to start against, provided by the weight or static pressure of the water above the impellers. These pumps, therefore, can usually be started with the discharge valve in the open position.

Another aspect of pump operation and maintenance that requires some discussion is the subject of PACKING. Although this topic is included here under the general heading of centrifugal pumps, packing is employed on many other types of pumps as well. Figure 6-14 shows packing installation procedures for centrifugal pumps.

Packing is a general term which refers to many different types of materials that are used to seal moving machinery joints (sliding pistons and piston rods, rotating shafts and valve stems, etc.) against leakage of steam or liquids. As such, packing can be thought of as a close-fitting bearing which must not only prevent leakage, but must also do this without causing excessive friction and undue wear of the moving part. Although most packing has definite lubricating qualities of its own, lubrication must normally be enhanced by permitting small amounts of liquid or steam to leak past or through the packing. If the pump handles corrosive or abrasive fluids, then some other form of lubricant, such as grease or oil, must be fed to the packing through external means.

Packing usually takes the form of coils, rings, spirals, and the like. The packing is inserted into a stuffing box fitted around the sliding or rotating joint. The compression of the packing around the joint (and, therefore, the leakage) is controlled by hand-adjusted gland nuts.

The selection of the proper type of packing for a particular pump is of paramount importance. There is no such thing as general purpose or all purpose packing. The specific type of packing that must be used will depend on several factors, two of these variables being whether the packing will seal a rotating or sliding joint, and the type of liquid handled by the pump. In any event, the selection of packing will not require a judgment on your part. Locally prepared guides and/or manufacturer's instructions will specify exactly what type of packing material must be used.

Upon receipt of packing, note its condition and the use date stamped on the package. This will help you in determining the shelf life of the packing. If a package containing packing has become unsealed, reseal it if necessary. For best results, see that packing is used before expiration of its use date.

Packing will require frequent inspection and adjustment, particularly while the pump is in operation. Adjustment of the gland nuts must be done with particular care so that all the packing is compressed evenly and equally around the joint. If this is not done, excessive and uneven wear of the packing may result, and the rotating or sliding shaft may become scored or grooved.

When a pump is first started, lubrication of the packing may be relatively poor. Due to initial friction, the packing may heat up and expand, thereby compressing itself around the joint and further reducing lubrication or leakage. Merely loosening or backing off the gland nuts is not always the best solution since the liquid pressure in the pump can force the complete set of packing to move outward in the stuffing box. In this instance, the pump may have to be shut down and the stuffing boxes allowed to cool. Several restarts may be necessary before the stuffing boxes run cool.

There are many additional and detailed procedures which have to do with packing, but which are too extensive to be covered here. The primary purpose of this relatively brief discussion of packing is to alert you to the vital importance of this pump component. It has been said that the proper inspection, adjustment, and up-keep of packing is the most abused aspect of pump operation and maintenance.

AIRLIFT PUMPS

The use of airlift pumps is confined entirely to well pumping. Unlike the other pumps we have studied, the airlift pump needs no moving or

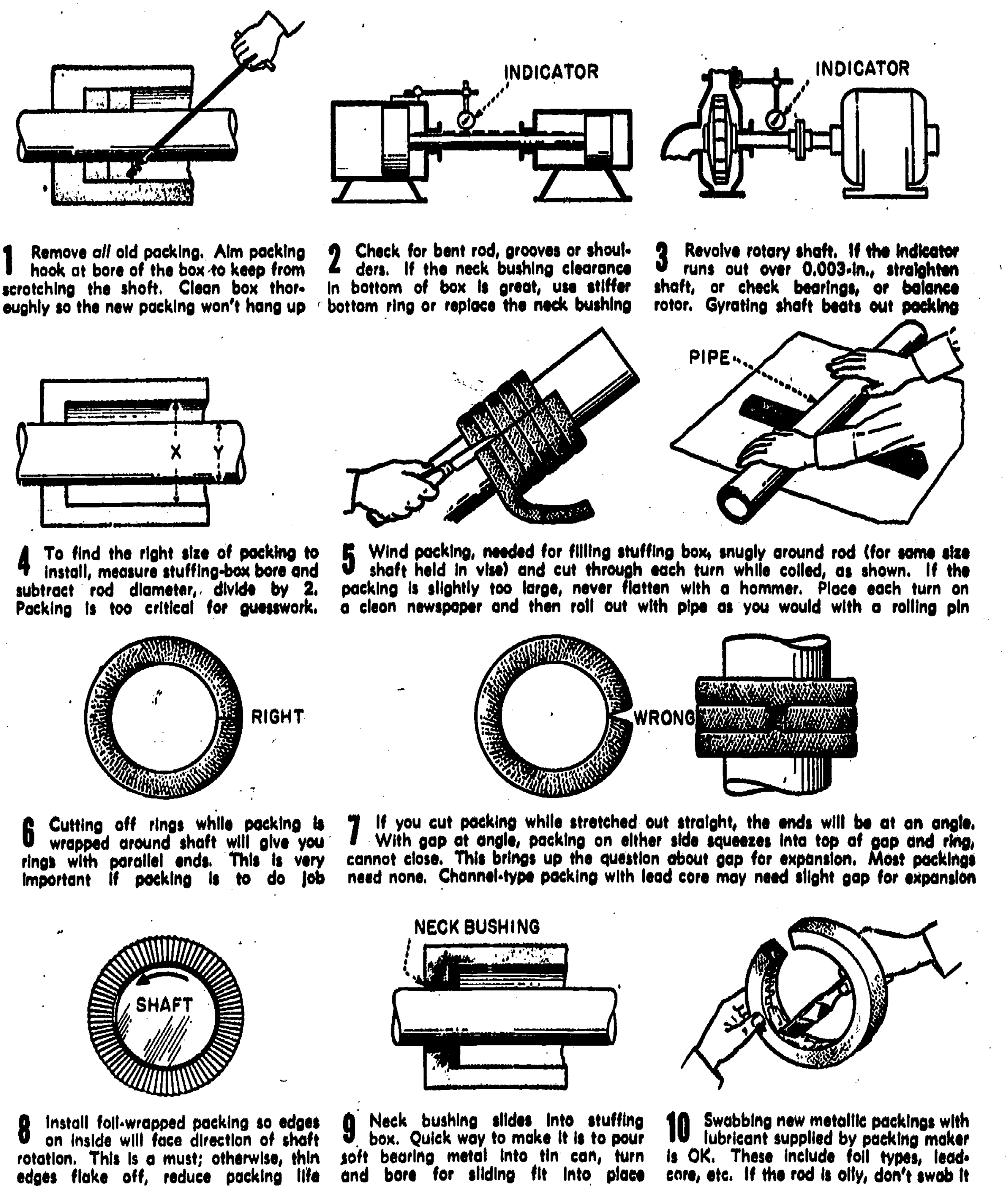


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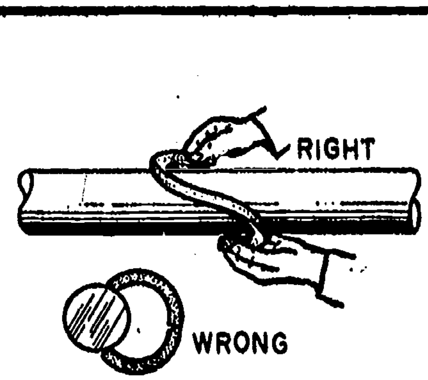
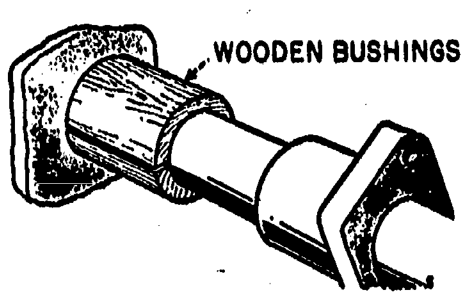
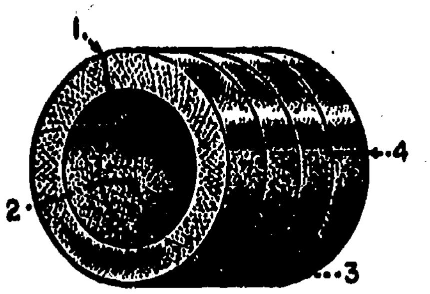
Figure 6-14. — Packing installation procedures.



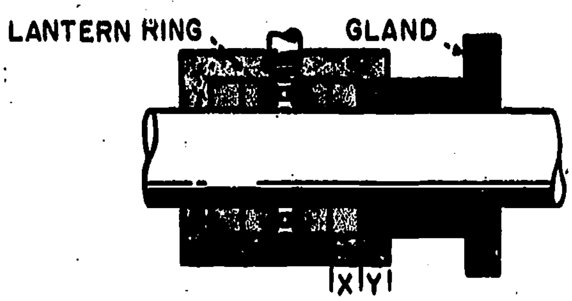
11 Open ring joint sidewise, especially lead-filled and metallic types. This prevents distorting molded circumference—breaking the ring opposite gap



12 Use split wooden bushing. Install first turn of packing, then force into bottom of box by tightening gland against bushing. Seat each turn this way



13 Stagger joints 180 degrees if only two rings are in stuffing box. Space at 120 degrees for three rings, or 90 degrees if four rings or more are in set



14 Install packing so lantern ring lines up with cooling-liquid opening. Also, remember that this ring moves back into box as packing is compressed. Leave space for gland to enter as shown. Tighten gland with wrench—back off finger-tight. Allow the packing to leak until it seats itself, then allow a slight operating leakage.

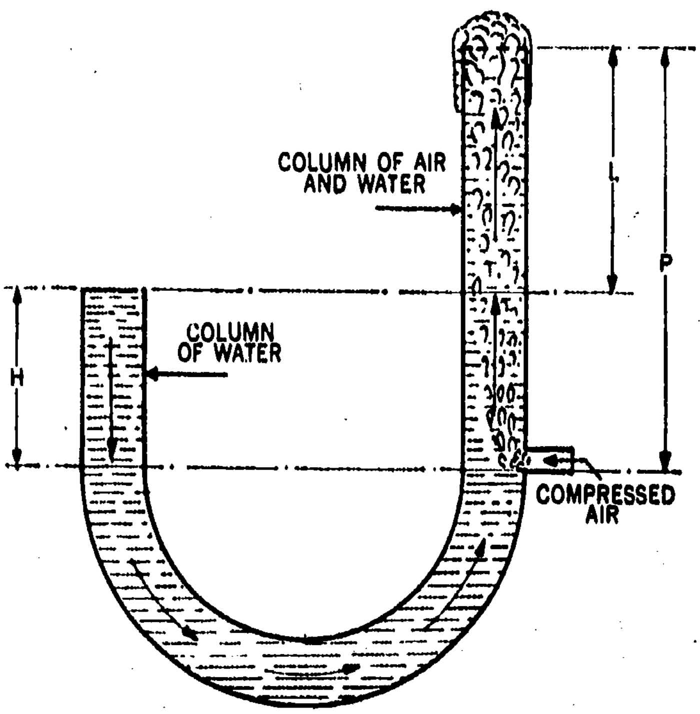
87.201.2X

Figure 6-14.—Packing installation procedures—continued.

rotating mechanism to produce liquid movement. Instead, the pump utilizes compressed air to move or lift the liquid.

The airlift pump operates on the pinciple that water mixed with air has less weight, or is more buoyant, than water which contains no air. When compressed air is introduced, a mixture of water and air is formed in one leg of the U-shaped pipe, as shown in figure 6-15. The solid column of water in the other leg now has greater weight, or is exerting a greater static pressure, than the column containing air. Thus, the air-water column is forced upward to the point where it discharges over the top of the U-shaped pipe.

In actual practice, of course, wells are not dug in U-shape. Figure 6-16 shows a CENTRAL AIRLIFT PUMP. Compressed air is led down an air pipe to a nozzle or footpiece submerged well below the water level. You will notice that the footpiece is suspended within a discharge pipe which, in turn, is contained within the well casing. Note, also, that the discharge pipe is open at the bottom, directly beneath the footpiece. When compressed air is discharged through the footpiece, a column or mixture of air is formed, above the footpiece, in the discharge pipe. The solid column of water in the well casing, resting high above the footpiece and discharge pipe inlet, now has greater weight or static pressure. This forces the air-water mixture upward in the discharge pipe to the point where it is vented to the atmosphere through an open discharge outlet. In effect, the flow of water has a U-shape: down the well casing, around to the footpiece, and up the discharge pipe. The air-water discharge then strikes a separator or deflector which serves to relieve the water of air bubbles and entrained air vapor. The discharge then settles in a collector tank.

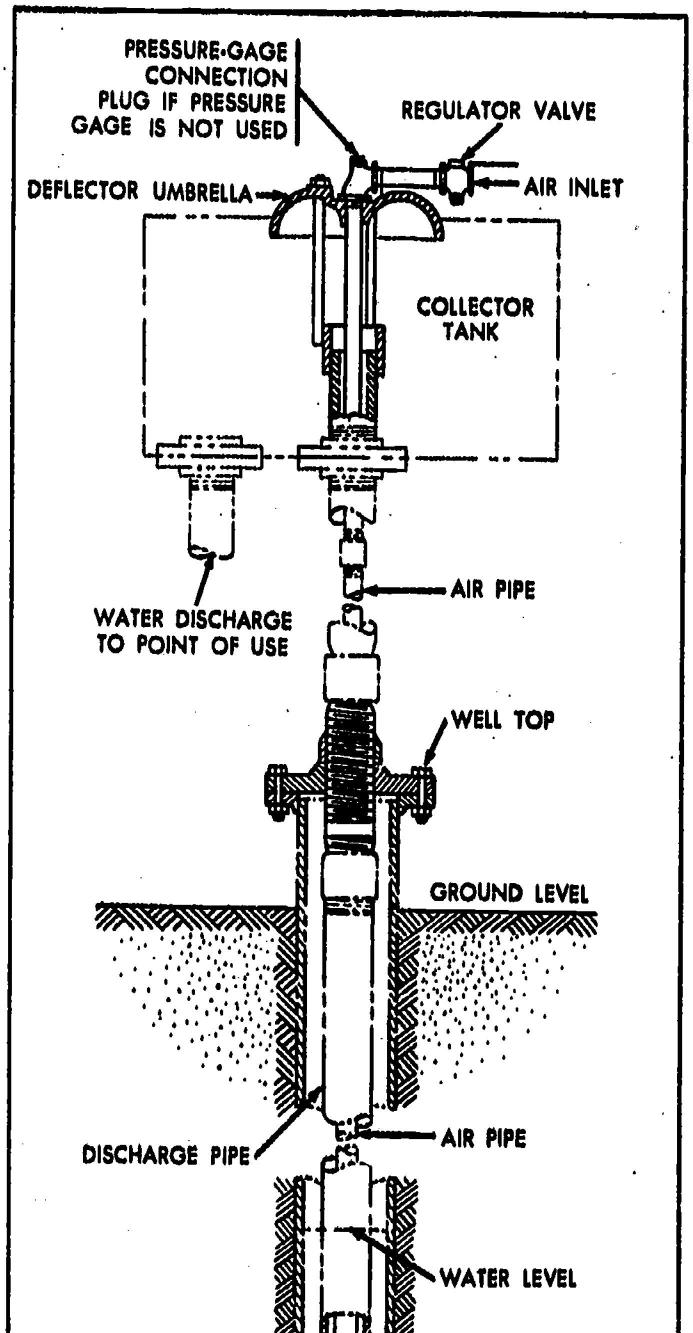


54.197
Figure 6-15. — Principle of airlift pump.

The airlift pump is capable of delivering considerable quantities of water in the manner just described. The discharge pressure at which it is delivered, however, is relatively low. For this reason, airlift pumps cannot be used to discharge directly into a water distribution system; that is, they do not develop sufficient pressure to distribute water horizontally above ground for any appreciable distance. Instead, the discharge is collected at the well for ground storage.

The capacity of the airlift pump will depend to a large extent on the percent submergence of the footpiece; that is, the greater the submergence of the footpiece below the water level in the discharge pipe, the greater the volume (column) of water the pump can deliver per unit time. However, the deeper the footpiece is submerged, the greater the compressed air pressure must be in order to lift the column of water. In other words, a higher column of water (in the discharge pipe) above the footpiece will exert a greater weight or pressure at the footpiece. The greater the static water pressure at the footpiece, the greater the air pressure must be in order to infuse air with the water properly.

It is also true that starting air pressure is always greater than working air pressure. When



54.198
Figure 6-16. — Central airlift pump.

the pump is started, the static (at rest) level of water is drawn down somewhat to a pumping or working level. In effect, the column of water above the footpiece is decreased or lowered, and this in turn decreases the air pressure required to infuse the water with air. In wells where the drawdown is rather large, the pump is sometimes equippped with an auxiliary air compressor, connected in series with the main compressor, for starting purposes. Once the pump has been started, and the pumping level reached, the auxiliary compressor is no longer required and is, therefore, secured.

The primary disadvantages of airlift pumps are low discharge pressure and the added depth required to obtain the proper submergence of the footpiece. Moreover, the entrained oxygen in air-lifted water tends to make it more corrosive. In spite of these drawbacks, airlift pumps have several important advantages, not the least of which is their simplicity of construction and consequent lack of maintenance problems. They are particularly useful in emergency deep well pumping, using a portable air compressor for power. They can be used to pump crooked wells and wells containing sand and other impurities. They can also pump hot water wells with little difficulty.

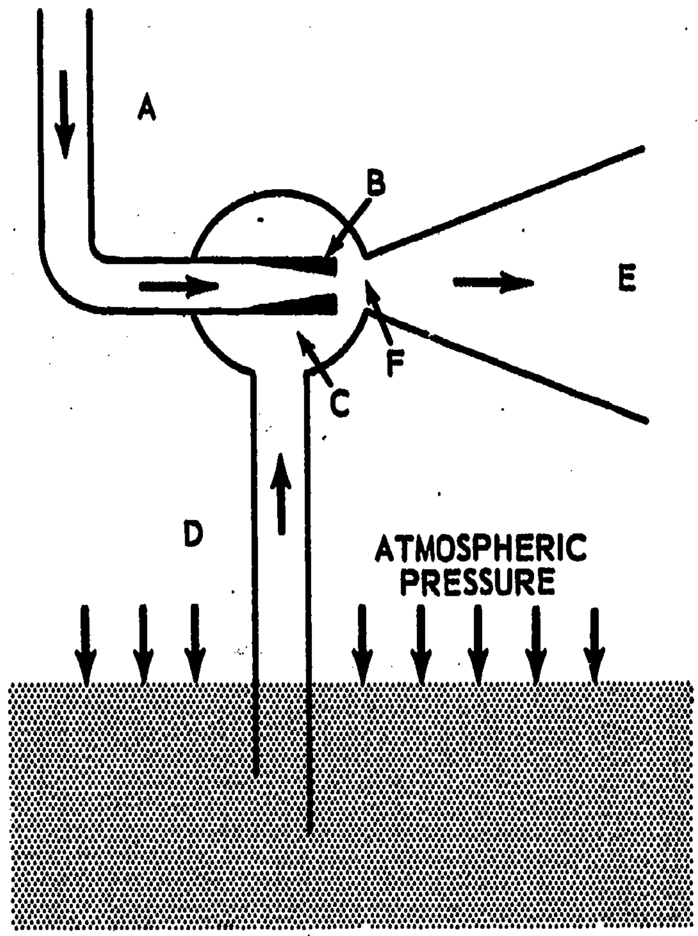
Operation and Maintenance of Airlift Pumps

Perhaps one of the most important aspects of airlift pump operation is the correct regulation of compressed air. The amount of compressed air used should be the minimum required to produce a continuous flow of water. Too little air results in water being discharged in spurts, or not at all. Too much air causes an increase in the volume of discharge but at lower discharge pressure. If air is increased still further, discharge volume begins to decrease.

The simplicity of the airlift pump is reflected in the fact that nearly all of the operating and maintenance inspections and procedures have to do with the air compressor (which will be described later).

JET PUMPS

Pumps which utilize the rapid flow of a fluid to entrain another fluid and thereby move it from one place to another are known as JET PUMPS. A jet pump contains no moving parts.



75.283
Figure 6-17.—Principle of operation of an ejector-type jet pump.

Jet pumps are generally considered in two classes: EJECTORS, which use a jet of steam to entrain air, water, or other fluid; and EDUCTORS, which use a flow of water to entrain and thereby pump water. The basic principles of operation of these two devices are identical.

The basic principle of operation of a simple jet pump of the ejector type is illustrated in figure 6-17. Steam under pressure enters chamber C through pipe A, which is fitted with a nozzle, B. As the steam flows through the nozzle, the velocity of the steam is increased. The fluid in the chamber at point F, in front of the nozzle, is driven out of the pump through the discharge line, E, by the force of the steam jet. The size of the discharge line increases gradually beyond the chamber, in order to decrease the velocity of the discharge and thereby transform some of the velocity head into pressure head. As the steam jet forces some of the fluid from the chamber into the discharge line, pressure in the chamber is lowered and the pressure on the surface of the supply fluid forces fluid up through the inlet, D, into the chamber and out through the discharge line. Thus the pumping action is established.

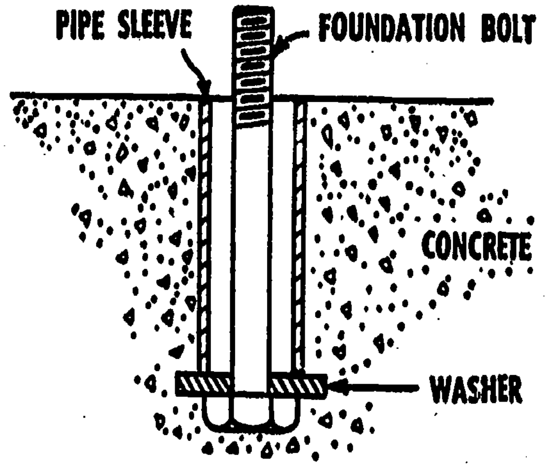
INSTALLATION OF PUMPS

As a Utilitiesman, you will be installing prime movers, pumps, and air compressors. The secret of success in operating prime movers, pumps, and air compressors is their proper installation. That puts the success of their operation directly in your hands. If you do your job right and the equipment is properly installed, it should perform satisfactorily for a long time. Of course, proper care and maintenance are also essential for continued efficient operation. However, even with the most perfect care and maintenance, you will find it difficult or impossible to overcome faulty installation.

The procedures for installing prime movers, pumps, and air compressors are basically the same. Therefore, we will discuss the basic procedures of pump installation. Remember that pumps, especially the centrifugal type, are built in many designs and for different purposes. Study the manufacturer's instruction manual for the equipment you are installing. Where specific directions or requirements are furnished, follow them.

When a pump unit is received by you from supply, there are a few points to check. First, make sure it is the correct pump for the job; do this by checking the nameplate data against that of the bill of material. Next, make a visual inspection of the unit to ensure there are no missing or loose parts. If the unit has a preservative covering (exterior or interior), make certain it is removed prior to being installed.

When pumps are to be installed, the locations will usually be determined in advance by higher authority and indicated on blueprints or sketches. However, there may be times when you will have to decide where to locate a pump. In most cases, the pump should be placed as close to the source of supply of water or other liquid as possible, so that the suction pipe may be short and direct and the suction lift will be comparatively low. In case of high temperature liquids, a suction head will be necessary. The pump should also be placed so that it will be accessible for regular inspection during its operation and that head room (a trap or ceiling opening) is available when it is necessary to use a crane, hoist, or tackle. If possible, a dry place should be selected, and the pump should be protected against the elements or weather.



54.400
Figure 6-18.—Pipe sleeve and foundation bolt.

The foundation of a pump must be substantial enough to absorb vibration and also to serve as a rigid support for the pump's baseplate. A concrete foundation or a solid base is most desirable.

Foundation J-bolts are embedded in the concrete foundation according to a blueprint or a template. The bolts should be longer than actually needed (3/4" to 1"), to allow for shimming up the pump to make it level and for grouting under the pump base. A pipe sleeve about 2 1/2 times the diameter of the bolt is used to allow for final positioning. If the bolt shown in figure 6-18 were 1 inch in diameter, a 2 1/2-inch pipe sleeve would be used.

A small pump is normally aligned and the two major parts bolted together before leaving the factory. The parts will not normally require alignment after the pump has been set on the foundation. Be careful that you don't spring them out of alignment. It is, of course, important that the pump be properly leveled and secured to the foundation. In setting the pump, a spirit level will be required; place the level on the machined surfaces in two directions. It may

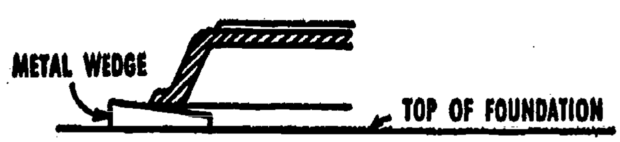


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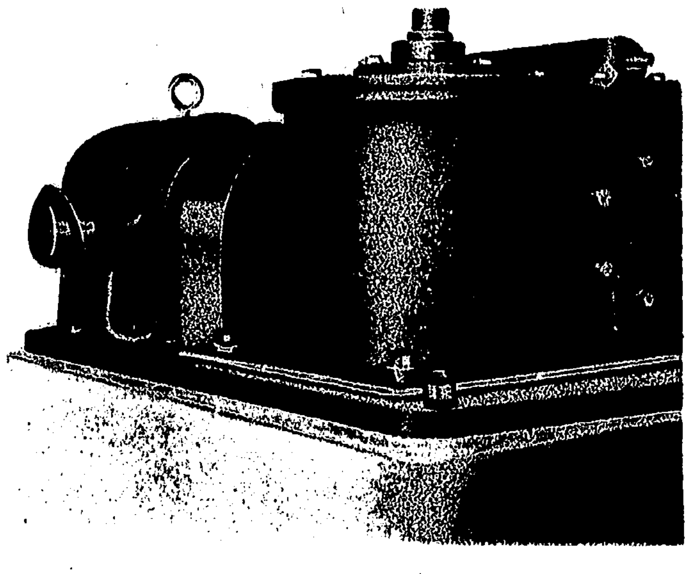
Figure 6-19.—Wedging a baseplate.



54.402
Figure 6-20.—Baseplate of a pump unit grouted to the foundation.

be necessary to remove the top casing or bearing cover to accomplish this. If a large sized pump is shipped in sections, you will have to align the water ends with the power ends after they have been placed on the foundation.

In leveling a pump unit, first use small metal wedges (as shown in fig. 6-19) and then place metal blocks and shims close to the foundation bolts. In each case, space the supports directly under the part carrying the most weight and close enough to give uniform support. Leave a gap of about 3/4 to 1 inch between the baseplate and the foundation for grouting with cement. (Grout is a mixture of cement, sand and water, making up a thin mortar.) Figure 6-20 shows a baseplate of a pump unit grouted to the foundation.

Adjust the supports or wedges until the shafts of the pump and the driver are level. By means of a level, check the coupling faces and suction and discharge flanges to see that they are plumb and level. If necessary, correct the positions by adjusting the supports or wedges as required.

In addition to checking for parallel alignment, you must check the angular alignment between the pump shaft and the drive shaft. You can do this by inserting a taper gage or feeler at four points between the coupling faces, as shown in figure 6-21. The points should be spaced at 90° intervals around the coupling. When the measurements are all alike and the coupling faces are the same distance apart at the four points, the unit will be in angular alignment. Correct any misalignment by adjusting the wedges or shims under the baseplate. Always remember that an adjustment in one direction may disturb adjustments made in another direction.

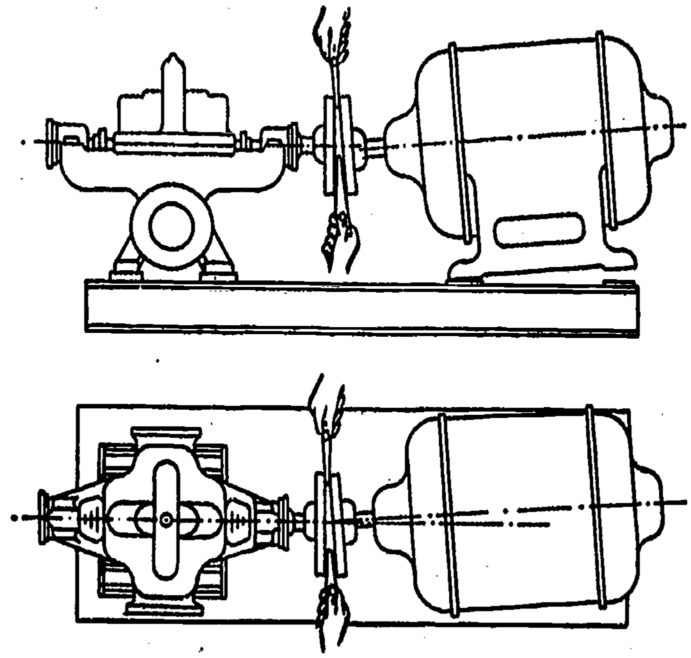


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Figure 6-21.—Making angular alignment.

A great many of the pumps used by the Navy are centrifugal pumps. Figure 6-22 shows a typical installation of a centrifugal pump. There are two types of assembly in which centrifugal pumps are delivered.

One group has the pump and driver mounted on a common baseplate at the factory. The other group has only the pump mounted at the factory, and the driver must be positioned at the place of installation. In the former group, factory alignment may not have been maintained, as all baseplates are flexible to some extent. Therefore, it will be necessary to realign the unit after it has been leveled on the foundation. To do this, first disconnect the coupling halves. Then follow the same alignment steps that have just been outlined. When they have been completed, reconnect the coupling and again check it for parallel and angular alignment.

If you are to install a centrifugal pump of the second group, you will have a little extra work. After you have placed the baseplate with the pump on the foundation, you level, align, and bolt it. Next, place the driver on the baseplate in accordance with the blueprints. Adjust the position of the driver and shim it up until

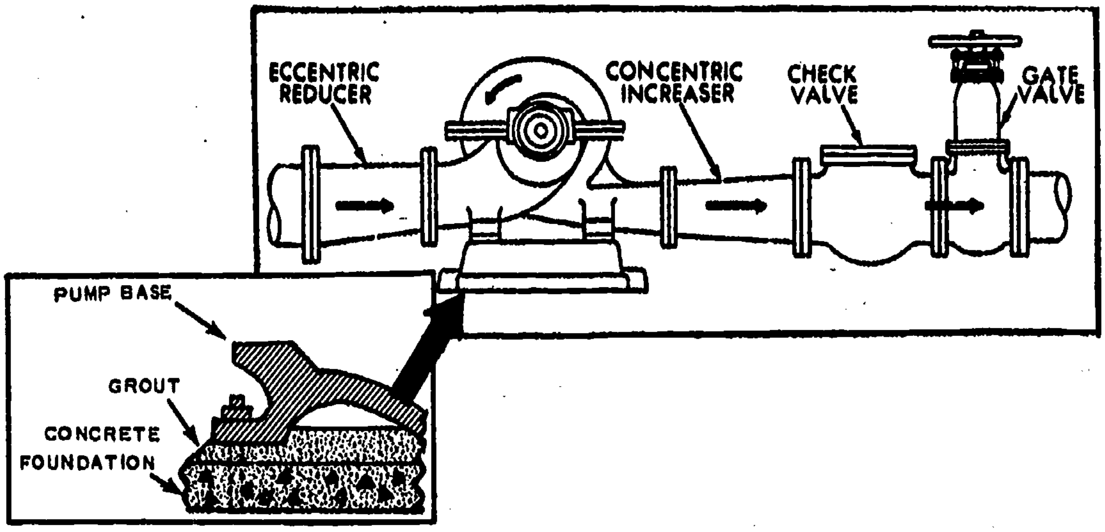

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Figure 6-22. — Typical installation of a centrifugal pump.

the pump and driver half couplings are aligned. Then bolt it securely and proceed as in the other installation.

In all cases, after you have correctly aligned the pump, tighten the foundation bolts evenly, but not too firmly. Then completely fill the baseplate with grout. It is desirable to grout the leveling pieces, shims or wedges in place. Foundation bolts should not be fully tightened until the grout has hardened, usually about 48 hours after pouring.

After the grout has set and the foundation bolts have been properly tightened, the pump should be checked again for parallel and angular alignment.

You are now ready to connect the piping. The pipes must line up naturally. Don't force them into place as this might draw the pump out of alignment. The pipes should also be supported independently so that they will not put any strain on the pump. One or more of these supports should be as near the pump as possible.

The size of the suction or discharge pipe leaving the pump is sometimes increased in order to reduce the loss of head from friction in the piping. Unnecessary bends should be eliminated from the piping to prevent loss of head. Eccentric reducers, as illustrated in figure 6-22, are usually recommended in the suction line to prevent the formation of air pockets. Whenever possible, bends should be made with the long radius. In order to remove the pump as easily as possible, flanged fittings or unions in all connecting lines should be used close to the pump.

After the piping has been connected, you should check the pump alignment again. Reconnect the coupling halves and start the pump. Let it warm up thoroughly and operate under normal conditions for a short time. Shut it down and immediately check for alignment of the couplings. All alignment checks must be made both with the coupling halves disconnected and again after they are connected.

It is important to check alignment in all directions after making any adjustment. You may find it necessary to readjust the alignment slightly, from time to time, while the unit and foundation are new.

SAFETY PRECAUTIONS FOR PUMPS AND PRIME MOVERS

In working with pumps and their prime movers, it is essential that you exercise care to avoid injury to anyone. Here are some safety precautions which you should observe.

1. Before operating or beginning work with pumps, make sure that all suction and discharge valves are closed and tagged.
2. Inspect for security of connections, particularly in the fuel system of the prime mover.
3. Do not fill the fuel tank with the engine running.
4. Ensure that the ignition switch is in the OFF position before making operational checks or attempting any repairs.

5. Disengage clutch (where provided) between prime mover and pump.

6. See that exhaust fumes are piped outside when pumps are to be operated in an enclosed area.

7. Stop operations before adding fuels or lubricants, either to the prime mover or the pump.

AIR COMPRESSORS

As the name suggests, air compressors are devices or machines which do nothing more than compress air. Basically, the compression process is one in which air, at normal atmospheric pressure, is taken and squeezed or pressed by some moving element within a confined space. In so doing, the volume of the air is reduced, but the pressure or force which that volume of air can exert is raised considerably. Thus, the air develops energy or power which can be put to some useful purpose in other machines. The compressed air need not be put to work immediately, but can be stored in tanks which preserve and maintain its pressure.

Compressed air can be taken from storage bottles or flasks and used to start diesel engines. That is, the compressed air is introduced into the diesel cylinders where, by virtue of its pressure, it forces the pistons to reciprocate until ignition temperature is reached. We have seen, too, how compressed air forces water to rise in wells. Air compressors are also used to drive or power a wide variety of pneumatic tools used in construction work.

There are several types of air compressors, such as reciprocating, centrifugal and rotary. In basic design and function, these compressors are quite similar to the pumps having the same names. In fact, air compressors are sometimes referred to as air pumps. Rather than discharging liquid at relatively high pressure, air compressors discharge air (which is considered to be a fluid) at high pressure. Like the pumps, compressors require some external source of mechanical power to accomplish this work. Prime movers for air compressors may be electric motors, internal combustion engines, steam turbines, and so on. The majority of air compressors used throughout the Navy are driven by electric motors.

RECIPROCATING AIR COMPRESSORS

One of the most commonly used air compressors in the naval service is the reciprocating air compressor. It compresses air in precisely the same fashion as a diesel engine: a reciprocating piston alternately draws in and then compresses the trapped air in a cylinder. Since there is no internal combustion involved, the cycle of the reciprocating air compressor is reduced or simplified to two strokes: suction (intake) and compression. Instead of operating the valves by cam action, as in internal combustion engines, the intake and discharge valves of the reciprocating air compressor operate on the principle of differential pressure overcoming spring tension, much the same as the check valves operate in reciprocating pumps. The suction stroke occurs as the piston moves downward, creating a partial vacuum which causes the intake valve to open. Air, at normal atmospheric pressure, is then drawn into the cylinder as the piston continues its downward movement. When the piston moves on the upward stroke, the intake valve closes. The trapped air is compressed as the piston continues its upward movement. As the piston reaches the top of its compression stroke, the air pressure developed is sufficient to overcome the resistance of the spring-loaded discharge valve. The discharge valve opens momentarily and the compressed air charge then passes into the discharge line.

If higher pressure is desired, additional cylinders or stages may be provided (see fig. 6-23). That is, the discharge of the first stage is led to the intake of the second stage, and so on. The principle involved here is virtually the same as in the multistage impeller arrangements used to increase the discharge pressure on centrifugal pumps. Figure 6-24 shows a more detailed view of a multistage reciprocating compressor. You can see that the second stage cylinder is noticeably smaller than the first. If there were additional cylinders, each would likewise be successively smaller. This reflects the compression process, whereby the volume of the air charge is continually reduced as it passes from one stage to the next; and, at the same time, the pressure becomes successively greater.

COMPRESSOR COMPONENTS

Air compressors are equipped with a valve arrangement which is generally known as an UNLOADING SYSTEM. The purpose of these valves, which vent the cylinders to the atmosphere, is to relieve the prime mover of the compression load during the starting process.

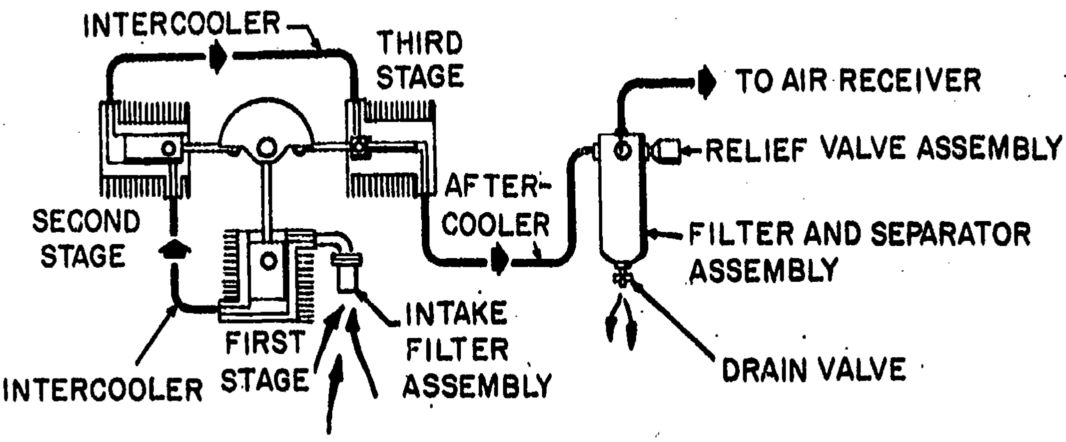

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Figure 6-23.—Air compressor assembly.

If no unloading valves were fitted, the pistons of the compressor would be working against peak compression pressure almost immediately, after only several revolutions of the prime mover. This would obviously overload the prime mover which has not yet attained its normal operating speed. To avoid this, the unloading valves will vent air within the compressor cylinders to the atmosphere while the prime mover is started and brought up to speed. Thus, there can be no compression in the cylinders, and hence, no compression load, until the prime mover has reached operating speed and is capable of assuming the load. Suffice to say that most unloading systems operate automatically. You may, however, find some older types of compressors fitted with hand-operated unloading valves.

Since compressors draw in ambient air, or the air surrounding the compressor, the intake is fitted with an AIR INTAKE FILTER. The purpose of the filter is to keep intake air free of dust and other airborne particles. If dus-laden air were permitted to enter the compressor, there would be a distinct danger of internal combustion within the cylinders, triggered by the heat of compression.

Moist or humid air which is drawn into the compressor cylinders poses another problem. The air intake filter cannot prevent this water vapor from being taken into the compressor. Instead, the water vapor is usually squeezed out of the air during the compression process and transformed into steam (by the heat of compression). The steam, however, will condense to form moisture droplets downstream from the compressor as the compressed air charge is cooled. Since moisture can have a decidedly adverse effect on some of the machines which use compressed air (pneumatic tools, for example), the moisture must be removed from the air before it is sent to the storage tank. For this reason, a FILTER AND MOISTURE SEPARATOR ASSEMBLY is placed between the compressor and storage tank. The assembly removes the greater part of the moisture, or any other impurities, entrained in the air before it is sent on to storage. The assembly is fitted with a valve or drain cock so that accumulations of water and dirt can be drained periodically by the operator.

The tank which stores the compressed air is called the AIR RECEIVER. Whatever demands are made for compressed air, they are made upon the receiver rather than directly on the compressor itself. In this way, the possibility of the demand for air exceeding the supply is considerably reduced. To this end, the air receiver has associated with it some type of control system or device which monitors the supply of compressed air in the receiver. The control device may be of the PRESSURE SWITCH type which senses predetermined thresholds or levels of pressure. When the compressor has sufficiently charged the receiver with compressed air, the pressure switch will automatically open and thereby shut down the compressor. If and when the demand for compressed air begins to drain the receiver to a preset pressure threshold, the pressure switch will close and automatically start the compressor.

In the case of systems where the demand for air is more or less constant and prolonged, a type of CONSTANT SPEED CONTROL can be employed. The compressor is permitted to run

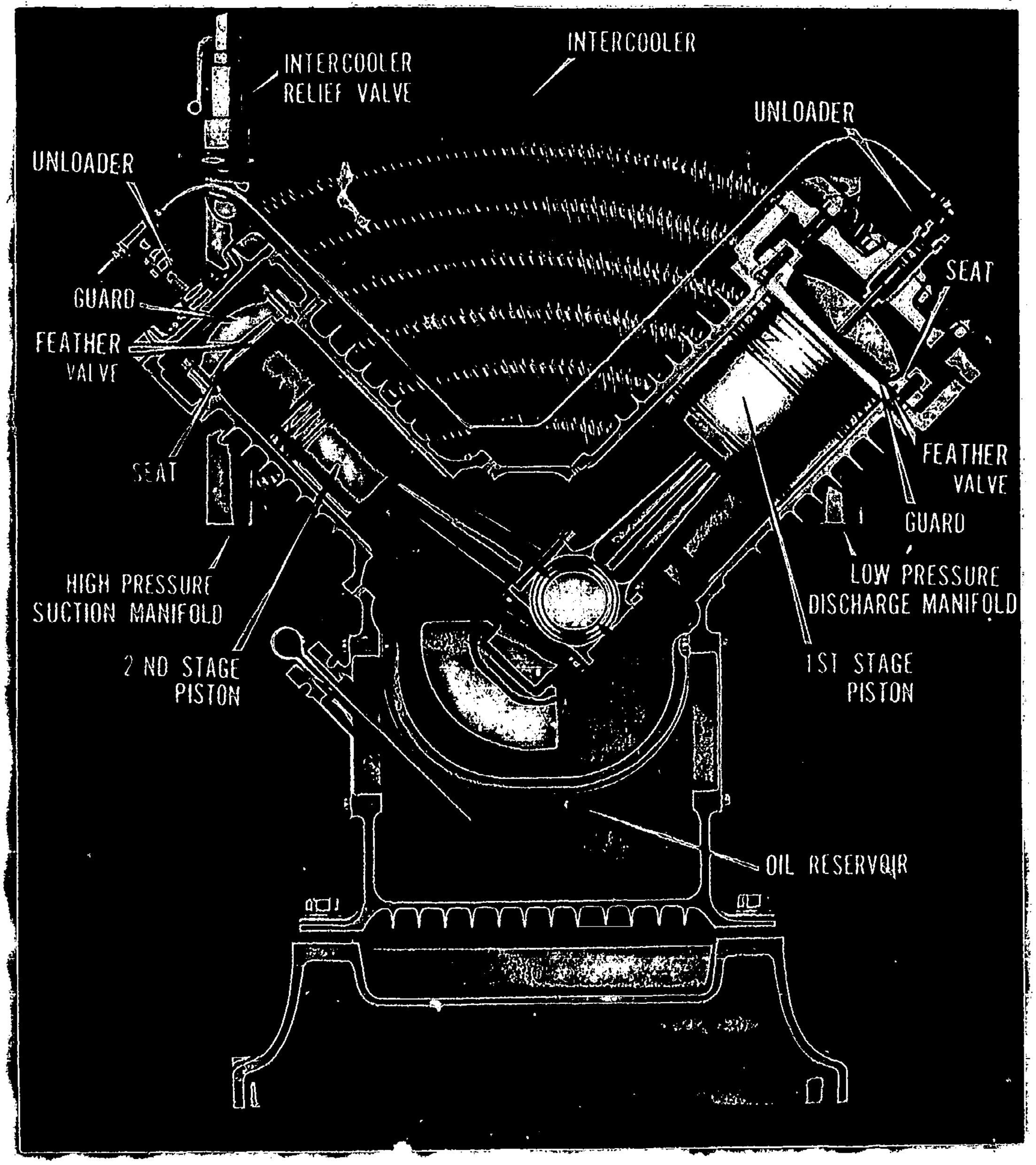

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Figure 6-24.—A two-stage reciprocating air compressor.

continuously, keeping the receiver charged with air, while the constant speed control functions somewhat like a pressure relief valve. If the pressure of the compressor air in the receiver rises, due to a momentary drop in demand within the system, the control will simply vent the excess compressed air to the atmosphere, rather than shut down the compressor.

COMPRESSOR COOLING SYSTEMS

The generation of heat always accompanies the compression of air. In most low-pressure air compressors, the heat which results from compression is dissipated before the temperature attains a troublesome level. This is accomplished through the use of aluminum cylinders with cooling fins and a fan which forces cooling air past the cylinders. In most medium-pressure and high-pressure air compressors, it is necessary to cool the compressor with pump-circulated water. The cooling water is circulated in much the same fashion as in an automobile engine, the coolant passing through jackets in the cylinder walls, cylinder heads, and so on.

In addition, compressors are fitted with other cooling devices known as intercoolers and aftercoolers. Generally, these devices consist of a series of tubes, which are either air-cooled or water-cooled, through which the compressed air charge flows after leaving the cylinders. The purpose of these devices is to cool the compressed air. INTERCOOLERS are placed between the stages or cylinders of multistage compressors. Thus, they cool the compressed air charge before it is drawn into the next cylinder. The AFTERCOOLERS cool the final discharge of air from the compressor. Both the intercoolers and the aftercoolers are of the same general construction, except that the aftercoolers are designed to withstand a higher working pressure.

Perhaps the most important advantage of these coolers is that they aid in keeping the air charge in a compressed state. In other words, hot air has a tendency to expand, and if the compressed air charge were not cooled, it too would have a tendency to expand and thereby liberate much of its pressure or energy.

OPERATION AND MAINTENANCE

Prior to starting the compressor, the operator will be required to make various inspections to ensure that both the compressor and the auxiliary components are ready for operation. This procedure will include: checks of the control and unloading systems; inspection of safety valves or pressure relief valves; draining condensate from the coolers, separator, and receiver; turning on cooling-water services and opening whatever valves are necessary to ensure proper circulation of water through the compressor and coolers.

Once the compressor is in operation, the operator must periodically check the temperature and pressure of the cooling water, lube oil, and compressed air. The lube oil level must also be checked and maintained at the proper level. Coolers must be inspected for correct temperature and flow of water. Accumulations of moisture in coolers, separator, and air receiver must be drained periodically.

In addition, maintenance schedules will also require more detailed inspections (monthly, quarterly, etc.). In many cases, these inspections will require dismantling parts of the compressor and auxiliary equipment. For instance, the operator may be required to inspect intake and discharge valves, cylinders, and pistons. The air intake filter must be inspected periodically and cleaned as necessary. Coolers must be inspected and receiver must also be inspected for corrosion and accumulations of dirt and oil.

The lubrication system on most compressors is somewhate similar to that found on an automobile engine. Normally, the compressor base is used as the lube oil sump and oil pump housing. The oil level can be measured by a dipstick or an oil level sight gage mounted on the base. The lube oil is distributed through various passages to lubricate bearings, valves, pistons, and other internal parts. An oil film is also distributed over the cylinder walls. Although small amounts of lube oil may mix with the compressed air, it is usually filtered out at the separator assembly. You might note in this connection, however, that one of the periodic operator inspections on airlift pumps is to check the air-water discharge from the pump for possible contamination by lube oil entrained in the compressed air.

The proper selection of the lube oil to be used in the cylinders is, of course, quite important. The auto-ignition point (temperature at which oil vapor will burn without the presence of a spark or flame) of these oils must always be well above the highest heat of compression. Otherwise, there is the danger of internal combustion in the compressor cylinders.

SAFETY PRECAUTIONS

To avoid air compressor accidents you must observe the following safety precautions:

The hose connections of portable air compressors must be kept tight. These connections shall be inspected frequently to be sure that they stay tight in service.

The safety valves and gages must be checked frequently so that there will be no doubt that they are in good operating condition.

Fixed tow bars should always be used when transporting this equipment. Chains and ropes should not be employed when moving it from place to place. This equipment should not be towed at a speed beyond that for which the wheel bearings are designed.

The wheels of portable air compressor carriages must be checked regularly to be sure they will operate safely when they are used.

All the usual safety aspects of motors, air compressors, and air receivers must be considered to assure safe operation of this type of equipment.

When starting an air compressor, check the safety valves, pressure controls, and regulators to determine that they are working properly.

Do not leave the compressor station after starting the compressor unless it has been made certain that the control, unloading, and governing devices are working properly.

Do not run an air compressor faster than the speed recommended by the manufacturer.

Be sure air at the intake is cool and free from flammable gases, vapors or dust.

Do not permit wood or other flammable materials to remain in contact with the air discharge pipe.

Immediately secure a compressor if the temperature of the air discharged from any stage rises unduly or exceeds 400° F.

Do not install a stop valve or check valve between the compressor and receiver unless a relief valve is also fitted between the compressor and the stop or check valve. (If the compressor is started against a closed valve or a defective check valve the air cannot escape and an explosion will result.)

Pressure gages should never be rendered inoperative except when they are to be removed for some valid reason.

Never kink a hose to stop the air flow. Keep the clamps on the hose tight.

Keep compressor, tanks, and accompanying piping clean to guard against oil vapor explosion. Clean intake air filters periodically.

Use only soapy water or another suitable nontoxic, non-flammable solution for cleaning compressor intake filters, cylinders, or air passages. Never use benzene, kerosene, or other light oils to clean these portions of a system. These oils vaporize easily and will form a highly explosive mixture under compression.

Turn off the motor before making adjustments and repairs on an air compressor.

Before working on or removing any part of a compressor, make certain that the compressor is secured and cannot be started automatically or by accident, that air pressure in the compressor is completely relieved, and that all valves between the compressor and receivers are closed.

CHAPTER 7
FIELD WATER TREATMENT EQUIPMENT AND PROCESSES

Water treatment is closely related to the health of a unit. Improper treatment of water can cause infectious intestinal diseases and skin fungus. The responsibility of ensuring a supply of pure water in the Seabees is shared by the unit commander and the Navy Medical Service. As a Utilitiesman, you will perform major duties involving the treatment and purification of water so that it will be safe to use for drinking, cooking, bathing, and so on.

This chapter will brief you on various diseases which are caused by use of water that is not pure and safe. You will learn some of the field methods of treatment and purification used to eliminate impurities in water. You will also be introduced to some of the various types of purification and distillation equipment with which you, as a UT, should be familiar.

WATERBORNE DISEASES

Water can be a source of danger and destruction because of the many impurities often found in it. Actually, you can expect to find impurities in practically all water. Some of these impurities do not amount to much, while others are extremely dangerous to health. Impurities in water can be broken down into two major categories: dissolved impurities and suspended impurities.

DISSOLVED IMPURITIES are organic or inorganic materials or chemicals which may cause an unpleasant taste, color, or odor in the water.

SUSPENDED IMPURITIES include organisms, as well as organic and inorganic materials which usually make the water turbid or muddy-looking. Waterborne diseases caused by dangerous organisms include typhoid, paratyphoid, cholera, amoebic-dysentery, schistosomiasis, and diarrhea. A brief discussion of these waterborne diseases, which will spread if proper treatment is not given to water supply, will help to stress the importance of continual care and inspection.

TYPHOID FEVER is an intestinal disease caused by the bacterium known as bacillus typhosus. Symptoms of this disease are rose-colored eruption of the skin, accompanied by a high fever (lasting about 4 weeks) and frequent bowel movements. Typhoid fever organisms are readily destroyed by field chlorination methods. Most waterborne diseases do not appear immediately after using contaminated water, as they need time to grow after entering a person's system. This period is known as the incubation period.

PARATYPHOID is similar to typhoid in sources of infection and in symptoms; the organisms are, like the typhoid bacillus, readily destroyed by field chlorination methods.

The incubation period varies from 4 to 10 days. An attack gives a man immunity from a second attack of paratyphoid, but does not give immunity from typhoid.

CHOLERA germs are discharged from the body in feces where they live for several days. When water in any form contacts this germ it is carried along and multiplies.

AMOEBIC DYSENTERY is an infectious intestinal disease. Symptoms are eruptions of the skin and frequent bowel movements. This disease is caused by a small animal rather than bacteria and resists ordinary chlorination. It is carried by amoebic cysts which foray in the intestines, then are discharged in the feces. Cysts (shell or sack) protect them and, when in water or moistened, they live for many days; but, drying destroys these cysts. The diatomite filter will, however, remove cysts. Superchlorination will destroy them.

SCHISTOSOMIASIS is caused by a small worm that may enter the body through consumption of contaminated water. Or, it may enter through the skin while a person is bathing or swimming in contaminated water. Eggs of this parasite (commonly called blood flukes) are discharged from an infected person through the urine or feces. In fresh water, these eggs hatch into very small, free-swimming larvae which are not infectious to humans. However, if these larvae find fresh-water snails into which they can enter, they develop into the next form "cercariae," and become highly infectious to human beings. In water, larvae can live for only 24 hours, and cercariae for only 36 hours. The effective remedy, therefore, is to kill all snails at the water source. Once the snails are destroyed, the cycle is broken and the disease ceases.

DIARRHEA is a name given to several intestinal diseases that are characterized by cramps and frequent bowel movements, with watery feces. Inadequate sanitary protection of food and water can cause diarrhea. Where the disease is caused by food, it is restricted to those who consume the contaminated food; waterborne infection is likely to be widespread. Proper chlorination measures will control waterborne diarrhea.

In addition to the specific waterborne diseases discussed above, there are several nonspecific disorders that are caused by impure water. One example is the staining or discoloring of teeth due to the presence of florides in drinking water. Surely you are well aware by now that maintaining a good safe supply of drinking, washing and bathing water — free from diseases and pollution — is one of your primary responsibilities.

TREATMENT AND PURIFICATION

Various methods of treatment and purification are used to eliminate impurities in water and, insofar as possible, make it pleasant to drink. You should be familiar with some of the principal methods commonly used, keeping in mind that safe, pure water is essential to naval operations everywhere. How well you carry out your duties involving the treatment and purification of water is a matter that will concern the health and welfare of all personnel using the water.

Various methods used in various combinations in the field treatment and purification of water include flocculation, sedimentation, filtration, disinfection, and distillation. A brief discussion on these methods follows.

FLOCCULATION

COAGULATION is a formation of gelatinous particles in water by chemical action. FLOCCULATION is the combination of these particles into a heavy precipitate (floc) which absorbs color and entangles bacteria and other suspended matter as it settles.

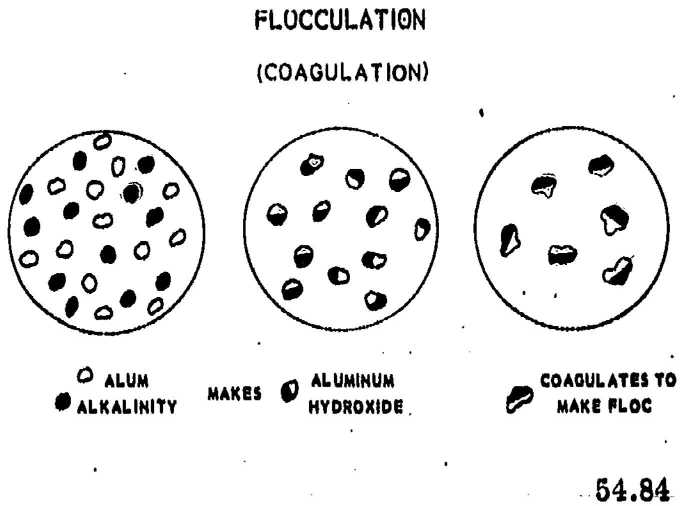

Figure 7-1. — Process of flocculation.

A common floc-forming chemical is aluminum sulfate (filter alum). If sufficient natural alkali is not present in the water to form a good floc, additional alkali (soda ash) must be added. Observe figure 7-1, which will give you an idea of how flocculation works. Mechanical devices such as mixers, agitators, and baffles are an advantage in flocculation since they keep the precipitate suspended in the water long enough to produce a heavy floc.

SEDIMENTATION

If you were to dip up a glassful of water from a moving stream and proceed promptly to observe its contents, you would probably discover a goodly number of solid particles being held in suspension in the liquid. At first these particles are more or less equally dispersed; but as the water becomes still, they start settling to the bottom of the glass. The settling of solids in this manner is caused by the natural action of gravity. In the water treatment field, clearing water of turbidity (that is foreign suspended matter) by this natural settling process is known as sedimentation. Sedimentation is accomplished in settling tanks, where the water is held for a time to allow the floc to form and settle out turbidity.

In conventional treatment, settling immediately follows flocculation. The ideal detention period for settling after slow mixing is about 1 1/2 hours.

FILTRATION

Not all of the suspended matter is removed by sedimentation. Therefore, another process known as FILTRATION is used. An effective type of filter used in filtration is the DIATOMITE. Because of its light weight, this filter is widely used at overseas bases. It removes suspended matter from water by passing it through a porous mat of diatomaceous silica. Diatomaceous silica is the skeletal remains of tiny algae, called diatoms, found in marine deposits which have been lifted above sea level.

The diatomite (also called diatomaceous earth or filter-aid) supported by a filter element. This supporting base is porous enough to permit maximum flow. It is also fine enough to support the filter cake that coats the element.

Diatomite filters are backwashed by reversing the flow of water and drawing filtered water through the filter. This is done whenever necessary to keep the filter output from falling off. The turbidity of the water will largely determine the frequency of backwash.

DISINFECTION

Except in rare instances, all water supplies require disinfection. Disinfection is the chemical destruction of bacteria. Because of its economy, dependability, efficiency and ease of handling, chlorine is almost always used for this purpose. The term CHLORINATION is generally used synonymously with DISINFECTION in water works practice.

Disinfection is a necessary step in the process of ensuring a safe water supply. All new, altered, or repaired water supply facilities must be disinfected before they are placed in service. Water from surface supplies may be disinfected before filtration, or before coagulation and sedimentation to prevent the growth of organisms. This procedure is known as prechlorination. It must also be disinfected after filtration to kill organisms that still remain, and to provide a safeguard against recontamination. This procedure is known as postchlorination.

Chlorine is the disinfectant specified for Navy use. In the form of chlorine gas, or of hypochlorites which yield chlorine in water, chlorine is presently the only widely accepted agent that destroys organisms in the water and leaves an easily detectable residual that serves as indicator of the completeness of treatment. The sudden disappearance of residual chlorine may signal contamination in the system. Under ordinary temperatures and pressures, chlorine gas is greenish-yellow and is heavier than air. Its effectiveness as a disinfectant depends on the temperature and pH of the water to which it is added. Disinfecting action is faster at higher temperatures, but is retarded by pH. If the pH is above 8.4, the rate of disinfection decreases sharply.

Ozone, potassium permanganate, bromine and iodine are also used to a limited extent as disinfectants. If excess lime is used for softening water, it makes the water alkaline and disinfects after about 10 hours of contact. However, the general applicability and economic advantage of chlorine has established it as the preferred disinfectant.

Chlorine Disinfectants

Chlorine disinfectants are available in a number of different forms as described in the following paragraphs.

LIQUID CHLORINE is liquified gas under pressure and is shipped in seamless steel cylinders under Interstate Commerce Commission regulations. The standard sizes of shipping containers are the 150-lb cylinder, 1-ton container, and 30-ton tank car.

Each pound of liquid chlorine produces about 5 cubic feet of chlorine gas at atmospheric pressure and at a temperature of 68° F. A standard Chlorine Institute valve and a protective valve hood are screwed into the neck of each cylinder. The valve has a safety plug containing fusible metal that softens between 157° and 162° F to protect the cylinder from bursting in case of fire. All cylinders must be factory tested every 5 years; 150-lb cylinders are tested at 500 lbs pressure and 1-ton containers at 800 lbs pressure.

HIGH-TEST CALCIUM HYPOCHLORITE is a relatively stable, dry granular solid or powder which is readily soluble, forming a chlorine solution. It is prepared under a number of trade names, including HTH, Perchloron, and Pittchlor. It is furnished in 3- to 100-lb containers and has 65 to 70 percent available chlorine by weight. Because of its concentrated form and ease of handling, calcium hypochlorite is preferred over other hypochlorites.

SODIUM HYPOCHLORITE is generally furnished as a solution that is highly alkaline, and therefore reasonably stable. Federal specifications call for solutions having 5 and 10 percent available chlorine by weight. Shipping costs limit its use to areas where it is available locally. It is also furnished as powder under various trade names such as Lobax and HTH-15. The powder generally consists of calcium hypochlorite and soda ash which react in water to form sodium hypochlorite.

Ordinary household bleach is a sodium hypochlorite solution containing 2.5 percent available chlorine and is sometimes used at small installations.

CHLORINATED LIME, also known as CHLORIDE OF LIME or BLEACHING POWDER, is seldom used in water disinfection. It is a mixture of calcium chloride and calcium oxychloride which will yield about 35 percent available chlorine when fresh. It deteriorates rapidly in hot moist atmospheres and should, therefore, be purchased in small packages that can be kept effectively sealed. Chlorinated lime contains an excess of insoluble lime; hence, solutions should be prepared in a separate container, the lime permitted to settle, and the liquid decanted into a separate tank for use.

Useful Terms

When chlorine gas is introduced into pure water, some of it reacts to form hypochlorous acid, and the rest remains as dissolved chlorine. These forms of chlorine are termed FREE AVAILABLE CHLORINE, because their oxidizing and disinfecting ability is fully available. Because most natural waters contain small amounts of ammonia and nitrogenous organic substances, free available chlorine will react with these substances to form chloramines and other complex chlorine-nitrogen compounds. These forms of chlorine compounds are termed COMBINED AVAILABLE CHLORINE; part of the chlorine oxidizing disinfecting ability is lost. Both free available chlorine and combined chlorine will react with oxidizable substances in water until their oxidizing and disinfecting ability is depleted. The amount of chlorine consumed in reacting with organic substances in a water in a given time (usually 10 minutes) is called the CHLORINE DEMAND. Chlorine remaining in excess of the chlorine demand is the TOTAL CHLORINE RESIDUAL, or RESIDUAL CHLORINE. Residual chlorine is composed of both free available chlorine and combined available chlorine. The time elapsing between the introduction of chlorine and use of the water is 30 minutes and is termed the CONTACT PERIOD.

Bactericidal Effectiveness

The bactericidal effectiveness of chlorine depends upon the chlorine residual, contact period, temperature, and pH.

Chlorine effectiveness increases rapidly with an increase in the residual. However, free available chlorine is 20 to 30 times as effective as combined chlorine under the most favorable conditions of pH (7.0) and water temperature (68° to 77° F). Therefore, the relative amounts of free and combined available chlorine in the total residual is important.

Within normal limits, the higher the chlorine residual, the lower the required contact period. If the residual is halved, the required contact period is doubled.

The effectiveness of free available chlorine at 32° to 40° F is approximately half of what it is at 70° to 75° F.

The effectiveness of free chlorine is highest at pH 7 and below. At pH 8.5, it is one-sixth as effective as at pH 7, and at pH 9.8, it may require 10 to 100 times as long for a 99 percent bacteria kill as at pH 7. Note that the pH scale is explained in chapter 10, so refer to that chapter in case you are not familiar with this scale.

Points of Applications

Plain or simple chlorination is the single application of chlorine as the only treatment before discharge to the distribution system, as in the chlorination of ground water supplies and previously unchlorinated purchased supplies. Prechlorination is the application of chlorine to raw water before coagulation, sedimentation, or filtration. Postchlorination is the application of chlorine after filtration, but before the water leaves the treatment plant. Rechlorination is the application of chlorine into the distribution system or into a previously chlorinated purchased supply to maintain the chlorine residual.

The above applications are normally continuous. Very heavy chlorination for a limited period is sometimes applied at specific points in the distribution system to destroy localized contamination.

Other Uses of Chlorine

Chlorine is also used to control tastes and odors in water. It reacts with the substances causing taste and odor, such as hydrogen sulfide, minute organisms, algae and organic compounds. If the reaction is incomplete, the taste and odor of some substances may be intensified or become more objectionable. Chlorine is also used to a limited extent to oxidize iron and manganese, and to remove color.

Safety

Safety is important in the handling of chlorine. The chapter on maintenance of water treatment plant equipment will acquaint you with safety precautions to be observed in the handling of ammonia, chlorine, and chlorine-yielding compounds. Carefully study those precautions and be sure and observe them in duties where applicable.

DISTILLATION

DISTILLATION refers to the process of purifying water by boiling and condensing the vapor produced. It is commonly used in the purification of sea water. It also may be used for water which contains excessive amounts of dissolved solids. In addition, distillation may be used in the purification of contaminated or polluted water.

In distillation units, heat boils water in an evaporator and changes the water into steam. The steam passes through a condenser, with distilled water being produced as a result. Figure 7-2 illustrates a distillation unit in its simplest form.

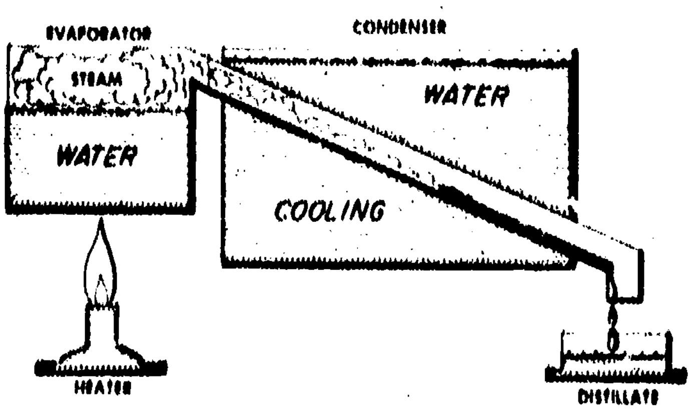

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Figure 7-2. Distillation unit in its simplest form.

54.87

Figure 7-3. — Lyster bag.

Do not overlook the importance of chlorinating distilled water. One reason for chlorination is the possibility of the water being contaminated by containers prior to its use. It is possible, of course, for distilled water to pick up dangerous organisms during dispensing. Maintaining a chlorine residual in distilled water provides a safeguard against this possibility.

TYPES OF PURIFICATION UNITS

At overseas bases you will find portable purification equipment which can be moved from place to place, as required. This equipment usually consists of comparatively small units. When you need more water than one small unit can produce, then two or more units may be used. Some of the types of purification units which you will be likely to use are discussed in following subsections.

LYSTER BAG

A Lyster bag (fig. 7-3) is primarily a dispensing unit for purified or distilled water. These bags are sturdy, watertight, and readily collapsible for packing. Water is withdrawn through small faucets at the bottom. When no

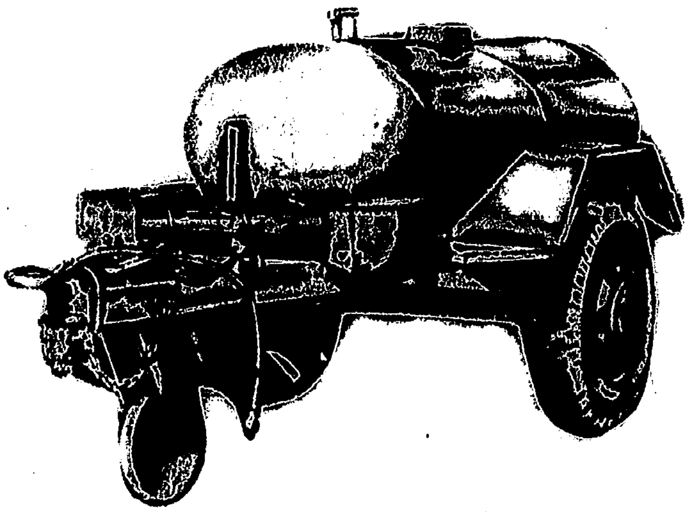

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Figure 7-4. — Tank trailer.

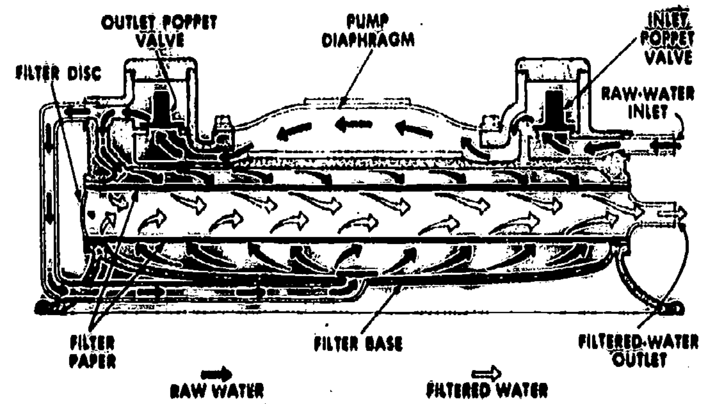

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Figure 7-5. — Flow diagram of water through the kit-type purification unit.

other purification equipment is available, a Lyster bag may be used to disinfect raw water. Normally, chemical kits for purification purposes are supplied with each Lyster bag. If you have occasion to use a Lyster bag, follow the treatment instructions supplied by the manufacturer of the unit.

TANK TRAILER

Tank trailers, like Lyster bags, also are designed primarily as dispensing units for purified or distilled water. Where necessary, however, tank trailers may be used to disinfect raw water. The water is treated as directed by local medical authorities.

A tank trailer holds approximately 300 gallons of water. (See fig. 7-4.) The unit comes equipped with faucets for dispensing the water. Where desirable, water may be transferred from the tank trailer into a Lyster bag. The Utilitiesman should make sure that a tank trailer has been properly cleaned and disinfected before filling it with water.

KIT-TYPE PURIFICATION UNIT

Another important piece of equipment is a hand pumping kit-type purification unit which has been designed for the use of small, isolated troop units. It may be used by initial landing units, patrols, parachute troops, or stranded personnel. This unit is durable and easy to operate. It will produce clear filtered water from turbid raw water at the rate of 1/4 gpm. It will also reduce the bacteria concentration in the water.

This unit is about 6 inches in diameter and 3 inches in height. It has a small hand-operated diaphragm pump, double-faced filter disk, base clamping ring, and suction and discharge hoses.

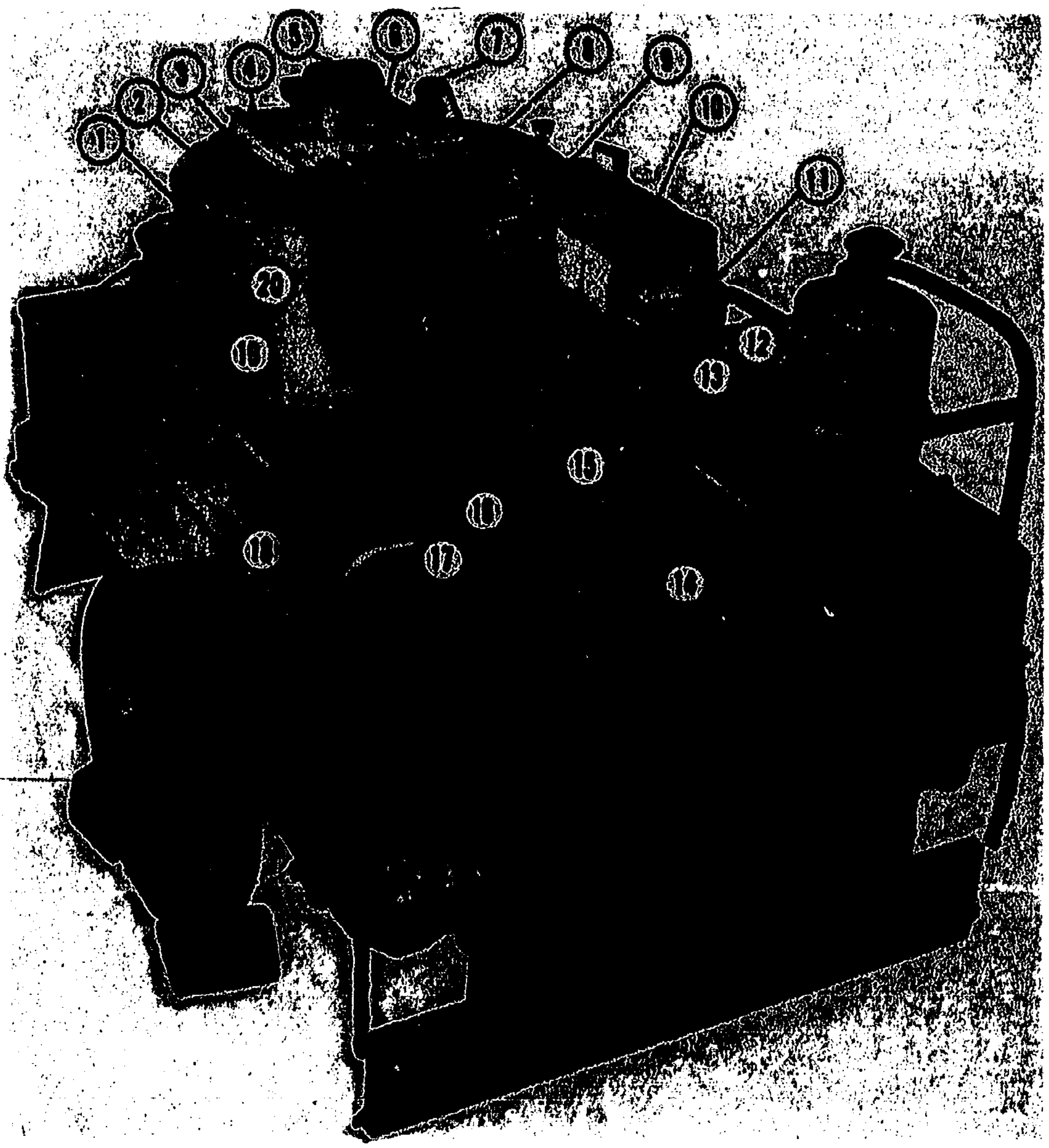
The raw water is drawn by the diaphragm pump through the suction strainer and hose. It enters the unit and is forced through the filter pads on the top and bottom of the filter disk (fig. 7-5). The filtered water then flows to the discharge hose.

You will find it easy to assemble and operate the unit. First remove the filter disk from the pump and base by releasing the clamping ring catch. Place a filter pad on top of the base, put the filter disk carefully on the pad, and then lay another filter pad on top of the disk. Be sure to keep everything clean and to place the smooth side of the filter pads against the disk.

The diaphragm pump is put on top of the filter disk and the three parts (base, disk, and pump) are clamped together. If the clamp is too tight or too loose, adjust the clamping ring at the hinge.

After you finish this assembling, check the suction hose to see if it is connected tightly to the unit. Then put the suction strainer in the water so that it will be able to take in water without being clogged by leaves or moss.

Now you are ready to filter raw water. Work the pump level at the rate of 70 to 80 strokes per minute. If no water is delivered after 1 or 2 minutes, check the strainer and suction hose for clogging or a loose connection to the pump. Also, check the poppet-valve caps for leaks.



1. Erdlator tank
2. Effluent launder
3. Effluent launder leveling rods (3 rqr)
4. Bridge rail
5. Agitator drive motor
6. Speed reducer
7. Air pump
8. Influent launder
9. Wet well tank
10. Sludge concentrator tank
11. Electric control box
12. Precoat funnel
13. Power cable
14. Pressure gages
15. Filter pump
16. Weir box
17. Erdlator mounting base
18. Chemical solution feeder
19. Storage box
20. Chemical slurry feeder

87.15

Figure 7-6.—Water purification unit mounted in trailer.

The water will flow through the filters and the discharge hose, and you can catch it in canteens or other containers. You are not ready to drink this water yet, as it has to be disinfected with iodine tablets.

When the flow of water from the discharge hose gets too small, it is time to change the filter pads. Usually, a filter pad set will filter at least 20 quarts of water.

Under the hinge of the pump lever is a small pressure-relief valve. This opens and discharges water if you pump too fast and the water pressure against the filter disk is too high. Slow down on your pumping rate to prevent opening the pressure-relief valve.

600-GPH WATER PURIFICATION UNIT

In the field you may also use the continuous flow, or erdlator, type of water purification unit. These units come in four sizes: a trailer-mounted, 600-gph unit; a van type body-mounted, 1500-gph unit; a van type body-mounted, 3000-gph unit; and a semiportable, knockdown type 10,000- gph unit. All types are constructed and operated in a similar manner, except that the erdlator tank of the 10,000-gph unit is constructed in three sections while that of the other three types is constructed in one piece. The following discussion applies to the 600-gph erdlator since this size will probably be more commonly used by the Seabees than the other three sizes.

The 600-gph water purification set is furnished in a special purpose cargo body, mounted on a 2 1/2-ton, 2-wheel trailer. The erdlator assembly, diatomite filter, filter pump, chemical feed equipment with the necessary piping and valves, and the electrical controls are mounted in the cargo body and are designed to be operated without removing them from the trailer body. (See figs. 7-6 and 7-7). Supporting equipment furnished with the purification set — but not mounted in the cargo body — includes a 3-kilowatt engine generator set, a gasoline engine driven pump, a portable electric driven pump, two-500 gallon collapsible water storage tanks, necessary hoses and fittings, water testing equipment, and a supply of chemicals.

Erdlator Assembly

The erdlator consists primarily of the following parts: tank, influent launder, effluent launder, wet well, sludge concentrator tank, slurry weir box, downcomer tube, agitator shaft with disks, agitator speed reducer, drive motor, air pump, bridge rails, and aluminum base. The erdlator assembly reduces the content of the organic and suspended matter of the water and produces an effluent suitable for application to the diatomite filter.

The erdlator tank (1, fig. 7-6) is a circular funnel-shaped unit of one piece aluminum construction, with a capacity of approximately 245 gallons. A stub shaft and bearing support for the agitator are mounted in the bottom of the tank. There is a ring near the bottom secured to the tank with a series of short baffles which support the downcomer tubes. A drawoff port is located opposite the weir box (16) and another near the top which opens into the wet well tank (9). There are two drains, an upper one for partial draining and a lower one for complete draining. The erdlator tank serves as a separator which hydraulically separates the slurry blanket from the clear water in the upper section of the tank in what is termed the separation zone (6, fig. 7-8). It also serves as a clarifier as the flow of coagulated water is directed in an upward rotation direction into the clarification zone (8).

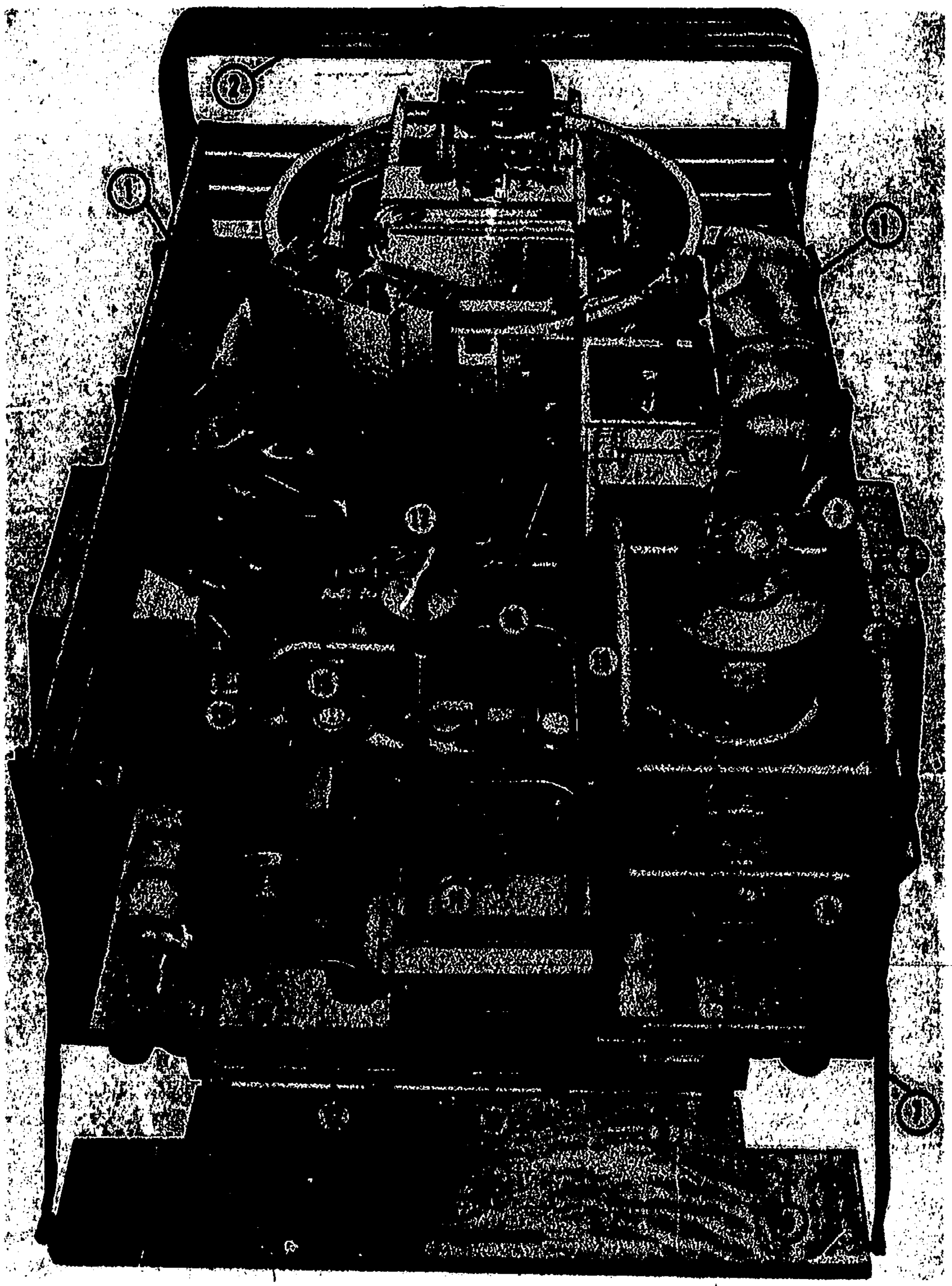
The influent launder (8, fig. 7-6) is of one piece aluminum construction and is attached to the two bridge rails. The raw water is introduced into the influent launder, through the aspirators, from where it overflows into the downcomer tube or mixing zone.

The effluent launder (2, fig. 7-6) is a one piece hexagon-shaped aluminum trough that surrounds the downcomer tube (1, fig. 7-8). It is attached to the bridge rails (4, fig. 7-6) by three leveling rods (3). It collects the clear water from the upper section of the erdlator tank and discharges it into the wet well tank (9).

The wet well tank (9, fig. 7-6) is made of aluminum and consists of a triangluar section welded to the rear quadrant of the erdlator tank for the collection of the effluent from the erdlator. It provides for limited storage of coagulated water, and serves as a sump for the suction of the filter pump. It contains an overflow pipe, to permit operation of the erdlator at rated capacity when the filter is stopped. A drain in the bottom of the wet well permits complete drainage of the tank to waste when water unsuited for filtering is obtained from the erdlator.

The sludge concentrator tank (10, fig. 7-6) is welded externally to the rear of the wet well tank. It is a square funnel-shaped aluminum tank with a shorter circular tank welded to its inside. There is an inlet in the side of the main tank near the bottom which permits the flocculent slurry to enter by gravity. The inner tank has an opening in the bottom controlled by a manually operated plug valve to permit intermittent drainage of slurry to waste. There is an outlet near the top of the main tank with a manually operated valve to control the flow of clear coagulated water to the wet well. There is also an outlet in the bottom for draining the tank.

The slurry weir box (16, fig. 7-6) is a small aluminum tank welded externally to the erdlator tank. It houses the drawoff port near the top of the erdlator tank and permits gravity flow of



1. Collapsible fabric tank, 500 gal. (2 rqr)
2. Roof bows
3. Air release valve
4. Filter tubular frame
5. Filter
6. Flow controller valve
7. Trailer tailgate chain
8. Trailer tailgate
9. Tool box
10. Chemical box
11. Distribution pump
12. Accessory box
13. Generator
14. Trailer body rack
15. Tank staves
16. Raw water pump with canvas cover
17. Pail tiedown strap and metal cover
18. Rubber pails
19. Filter pump

87.16

Figure 7-7.—Water purification set loaded in trailer.

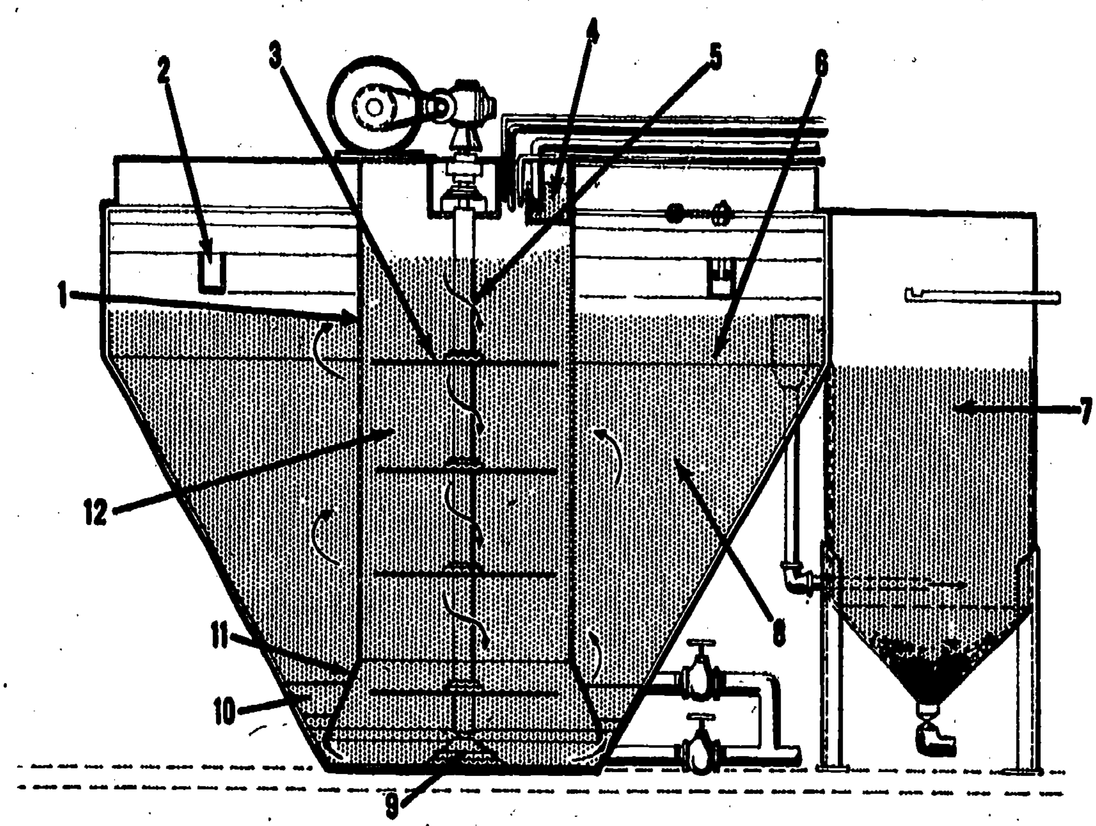


Figure 7-8. —Cross section of erdlator.

flocculent slurry from the erdlator tank to the sludge concentrator tank.

The agitator consists of a tubular shaft (5, fig. 7-8) with four equally spaced circular disks (3) attached. It is mounted in the center of the erdlator tank on the bearing support (9). The agitator is surrounded by the downcomer tube (1) and baffle ring (11) to form the mixing zone (12).

The speed reducer (6, fig. 7-6) is mounted on two spacers attached to the agitator bearing mounting plate. It reduces the drive speed from the agitator drive motor (5) to the erdlator agitator drive shaft.

The agitator drive motor (5, fig. 7-6) is mounted on a bracket attached to the bridge rails (4). It is a single-phase totally enclosed motor with oblong mounting holes in the base for use in adjusting the drive belt. The agitator drive motor also drives the air pump (7).

The air pump (7, fig. 7-6) is an oilless type with intake filter. It is mounted to the bearing mounting plate and driven off an extended shaft from the speed reducer (6). It is used to furnish air to the duplex chemical slurry feeders.

The bridge rails (4, fig. 7-6) consists of two aluminum channels attached to the top of the erdlator tank (1). They are used for supporting components of the erdlator located over the tank.

The filter section is mounted in a tubular frame (4, 7-7) and consists of a filter (5) specifically designed to use diatomaceous earth. A filter pump (19) is used for pumping the coagulated water through the filter. There are two pressure gages (14, fig. 7-6) for indicating the pressure on the effluent and influent sides of the filter. A precoat funnel (12) is used for adding prepared diatomite slurry for precoating the filter elements. There is also an air release valve (3, fig. 7-7) for releasing air trapped in the filter. A flow controller valve (6) for maintaining a fixed constant rate of flow through the filter, and additional valves and piping, are necessary for the operation of the filter.

The chemical slurry feeder (20, fig. 7-6) is an aluminum tank-like unit, mounted to brackets welded to the erdlator tank. It has two identical chemical compartments and water collection roughs, and two weirs, one of which contains a float-operated needle valve. One compartment supplies pulverized limestone slurry (coagulant aid), also activated carbon, to the mixing zone of the erdlator and the other supplies diatomite slurry to the suction inlet of the filter pump. A dial indicating timer is mounted on the lower part of the feeder.

The chemical solution feeder (18, fig. 7-6) is constructed of material having anticorrosive resistance and is mounted to the erdlator mounting base (17). It consists of two diaphragm pumps operated from one electric motor by means of a gear reduction mechanism. The chemical solution feeder pumps ferric chloride and calcium hypochlorite solution from two rubber pails into the mixing zone or downcomer (1, fig. 7-8) of the erdlator.

The filter pump (15, fig. 7-6) and the raw water pump are identical. Both pumps are centrifugal, vertical-type, powered by a self-contained, integrally built universal motor. The raw water pump is used for pumping the raw water to the erdlator. It is mounted in a tubular frame designed to mount on the erdlator base when the pump is not in use. The filter pump is used for pumping coagulated water from the wet well tank to the filter. It is mounted on the erdlator base (17).

The distribution pump (11, fig. 7-7) is a centrifugal type, gasoline-driven engine, mounted in a tubular frame. It is used to distribute the filtered water to the user.

The electrical control box (11, fig. 7-6) is mounted to the front of the sludge concentrator tank (10). It contains the circuit breakers, transformer, receptacles, switch, signal lamp, alarm buzzer, and the necessary controls and wiring to operate the components of the water purification unit.

Two collapsible, synthetic rubber-coated nylon tanks (1, fig. 7-7) are furnished with the basic issue items. Each tank has a capacity of 500 gallons. However, different type tanks may be used as required. These tanks provide storage for the filtered water.

A gasoline engine generator (13, fig. 7-7) is furnished with the basic issue items. The generator is capable of providing all the electrical power required for the operation of the water purification unit.

Sufficient hoses and fittings are furnished with the basic issue item to equip the water purification unit for pumping raw water from the source to the erdlator; filtered water from the filter to the storage tanks; finished water from the storage tank to the user; and waste water from the erdlator and filter to waste.

The unit is equipped with piping and valves of four different colors: black indicates raw water; yellow, coagulated water; red, waste water; and green filtered water.

Operation of Erdlator Tank

Raw water is pumped directly from the source into the erdlator tank. It is introduced at the top of the tank into the influent launders through the aspirators, which aerate the raw water. The water overflows from the influent launders into the mixing zone, where chemicals are added: ferric chloride, pulverized limestone, and calcium hypochlorite. When activated carbon is needed for a special purpose, such as decontamination or taste and odor control, it is also added here. It is well to note that the coagulation (pH) test is not used when continuous flow equipment is employed.

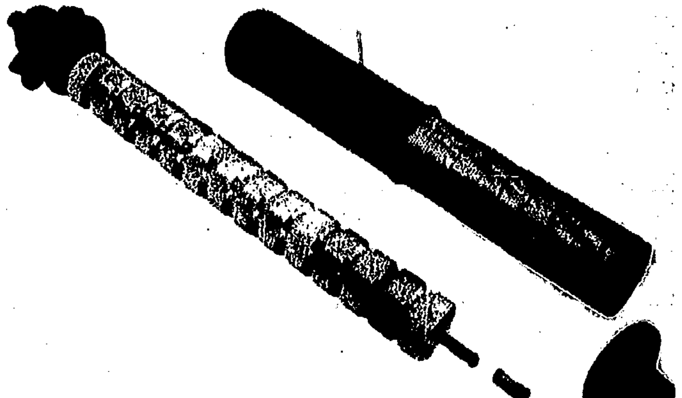
As the water and chemicals descend through the mixing zone, they are thoroughly mixed by the motion of four flat circular disks located at equal intervals on the rotating agitator shaft, at the center of the tank. This flow is a downward rotation. At the bottom of the tank are shallow baffles which deflect the flow and start it in a counterrotation.

The baffles direct the water into the clarification zone, the slant-sided area which surrounds the mixing zone. It is forced upward in a counterrotation at a reduced speed but continues with sufficient velocity to keep the slurry volume, together with the clear water above the slurry pool, rotating. The coagulants draw the solids into increasingly large particles which, because of their weight, tend to rise more slowly than the clear water which goes to the top of the clarification zone. These actions which take place in the mixing zone and the clarification zone illustrate the terms "solid contact" and "upward flow," used to describe the continuous flow water purification units.

There is a distinct separation of the clear water in the separator zone and the slurry in the clarification zone. At the top of the separator zone, the clear water is collected by the effluent launder and is continuously drawn off and discharged into the "wet well" tank. There it is stored until it is delivered into the filter. Besides providing storage space for clarified water, the wet well tank also acts as a sump for the suction of the filter pump.

The sludge concentrator tank is attached externally to, and at one quadrant of, the coagulator. The sludge concentrator tank functions as a small auxiliary coagulator. It draws slurry, still in the flocculent stage, from the clarification zone, and provides a longer holding period for slurry concentration than does the clarification zone itself. The sludge concentrator tank also permits settling of sludge to the bottom of the tank for continuous or intermittent drainage to waste, and skimming of clear coagulated water at the top of the tank for return to the wet well.

So far, the water has been subjected to the processes of coagulation, sedimentation, and chlorination, by one continuous flow process. Further purification of the water is necessary. Remaining solids must be removed by filtration. The diatomite system causes the water to be forced through a layer of diatomaceous earth and serves to remove the remaining suspended impurities. Properly operated diatomite filters are capable of removing from coagulated and settled water amoebic cysts, the cercariae of schistosomes, and approximately 90 percent of the bacteria, as well as producing water with less than one unit turbidity. One type of filter element is shown in figure 7-9.



87.18
Figure 7-9.—Filter element disassembled, showing plastic cups and plastic cover rolled back.

A slurry of diatomite and water is introduced into the filter to precoat the system before the filter is put into operation. The diatomite is held and supported on the filter element by the flow of water into the filter unit. During the filtering process, the porosity of the filter cake is maintained by the continuous addition of a small amount of diatomite slurry. When the pressure required to pump water through the filter increases, it indicates that the filter is clogging, and backwashing is necessary. To backwash the filter, the air release valve is opened. The air pressure under the filter dome is thus suddenly released, allowing the air in the filter element air traps to expand with the effect of a blast which knocks the diatomite and foreign matter off the filter elements. This is called backwashing by the air pump method. After the filter has been backwashed and drained, the filter pump should then be used to flush the filter, before the unit is again precoated and put back into operation.

Maintenance and Repair

As a Utilitiesman, it is your duty to ensure that the water purification unit is ready for operation at all times. In order to be in serviceable condition, it must be inspected periodically so that defects can be detected and corrected before they result in serious damage or failure. The necessary preventive maintenance checks and minor services for water purification units are listed in table 7-1.

HYPOCHLORINATION UNIT

Hypochlorination units are major water treatment items and are widely used at large overseas base establishments. They are designed to chlorinate water automatically. This is important where the water requires chlorination only, and the rate of flow of the water being treated is likely to vary.

The unit issued to overseas bases is complete with a by-pass fitting set and has a capacity of 2 to 100 gals per minute when installed in the line, and a capacity of 2 to 400 gpm when installed as a bypass. (See fig. 7-10.) It is used where the raw water supply is clear and found to be free from harmful amoebic cysts.

Table 7-1.—Preventive Maintenance Checks and Minor Services for Water Purification Unit

INTERVAL						B – BEFORE OPERATION D – DURING OPERATION	A – AFTER OPERATION W – WEEKLY M – MONTHLY Q – QUARTERLY
OPERATOR				ORG.			
DAILY							
B	D	A	W	M	Q	ITEM TO BE INSPECTED	PROCEDURE
X	X	X	X	X	X	Hoses, piping, valves, and tanks	Inspect all hoses and connections for leaks. Inspect all piping for damage. Inspect the aspirator nozzles for corrosion. Inspect the erdlator tank and the fabric tanks for leaks and other damage. Inspect all strainers for corrosion and other damage. Replace defective hoses. Tighten loose hose and pipe connections. Replace defective piping. Report a leaky erdlator tank to supervisor. Replace damaged aspirators. Clean or replace the strainers as necessary.
X	X	X	X	X	X	Chemical feed equipment	Inspect the chemical slurry feeder for leaks and defective float. Inspect the chemical slurry feeder timer for defective timing and insecure mounting. Inspect the chemical solution feeder for insecure mounting, loose electrical and hose connections, and unusual noise while in operation. Replace the slurry feeder float, needle valve, valve seat, and gasket, if damaged. Replace a leaking chemical slurry feeder. Tighten loose mountings. Replace a defective timer. Tighten loose electrical and hose connections. Replace the chemical solution feeder, if necessary. Replace defective chemical solution feeder pump valves, 0-rings, pump bodies, and diaphragms.
X	X	X	X	X	X	Filter and flow controller valves.	Inspect for loose connections. During operation, set the adjustable flow controller valve at a given rate of flow and measure the output of the valve. Check all the other valves to see if they operate freely and do not leak. Check the rate of flow of the nonadjustable flow controller valve in the raw water line during operation; it should be 10 gallons per minute. Tighten loose connections. Replace defective valves.

X		X	X	X	X	Filter assembly, diatomite	Inspect the diatomite filter for dirt, leaky gaskets, broken window or filter elements. Inspect for loose connections and insecure mounting. Inspect the pressure gages for cracked or broken glass, insecure mounting, and defective operation. Clean or replace filter elements, if necessary. Replace a defective window and gasket of the filter housing. Replace a broken or defective filter frame. See that pressure gages are securely mounted. Replace defective gages.
X	X	X	X	X	X	Diatomite filter air release valve	Inspect the valve for loose connections and signs of leakage around the flange bolts. Tighten all loose connections. See that all flange bolts are tightened evenly. Replace a defective air release valve.
X	X	X	X	X	X	Electrical control box and controls	Inspect the control box for insecure mounting. Inspect the warning buzzer, indicator light toggle switch, indicator light, receptacles, circuit breakers, and transformer, for loose mounting and damaged or defective parts. Replace defective or damaged buzzer, indicator light toggle switch, indicator light, receptacles, transformer, receptacles, and circuit breakers. See that all wiring and connections are tight.
X	X	X	X	X	X	Low water level float assembly and effluent launder	Inspect the wet well float assembly for a defective float or other damage. Inspect the effluent launder to wet well connecting tube for cracks, breaks, and loose mounting. Tighten all loose connections and mountings. Replace a defective float assembly. Replace a defective effluent launder adjusting rods. Replace the effluent launder to wet well connecting tube, if defective.
X	X	X	X	X	X	Chemical slurry air pump	Examine the air lines for damage and loose connections. Inspect the pump for misalignment with speed reducer and for insecure mounting and leaks. Inspect for a dirty or defective filter element (inspect element every 100 hours). Repair or replace defective air lines. Align the pump, if necessary, and tighten loose connections and mountings. Clean a dirty or clogged air filter. Replace a defective air pump assembly.

54.404

Figure 5-~~26~~27.--3/8" headed pins and threaded studs.

54.404.3

Table 7-1.—Preventive Maintenance Checks and Minor Services for Water Purification Unit—continued

INTERVAL						B - BEFORE OPERATION D - DURING OPERATION	A - AFTER OPERATION W - WEEKLY M - MONTHLY Q - QUARTERLY
OPERATOR				ORG.			
DAILY				M	Q	ITEM TO BE INSPECTED	PROCEDURE
B	D	A	W				
X	X	X	X	X	X	Agitator drive motor and belt	Inspect the motor for misalignment with speed reducer and for loose mounting bolts and wire connections. Listen for unusual noise during operation. Check for signs of worn bearings. Inspect the drive pulley for damage. Inspect the belt for excessive wear and proper adjustment. Proper adjustment is a deflection of 1 inch midway between the pulleys. Replace a defective motor.
X	X	X	X	X	X	Low water level sensitive switch	Inspect the switch for loose connections. Test the operation. See that the switch is clean and that all connections are tight. Replace a defective switch.
X	X	X	X	X	27	Speed reducer	Inspect for loose mounting. Listen for unusual sounds during operation. Inspect the condition and adjustment of the drive belt. The belt should be free of cracks and have one-inch slack at a point midway between the pulleys. Inspect the drive pulley for cracks or for being loose on shaft. See that the speed reducer is securely mounted. Replace defective coupling, keys, or pulley. Replace a defective speed reducer. Replace or adjust the drive belt, if necessary.
X	X	X	X	X	X	Raw water and filter pumps	Inspect for loose mountings, corrosion, cracked housing, and leaky seals. Inspect the pump motor brushes for wear. Tighten all mounting bolts and nuts. Replace a defective pump. Report defective seals to supervisor. Replace motor brushes if damaged or worn to ½ inch.
X	X	X	X	X	X	Controls and instruments	Inspect for damage. With the unit operating, inspect for improper operation. Normal readings are as follows: Influent pressure gage: 50 psig. Effluent pressure gage: 50 psig.

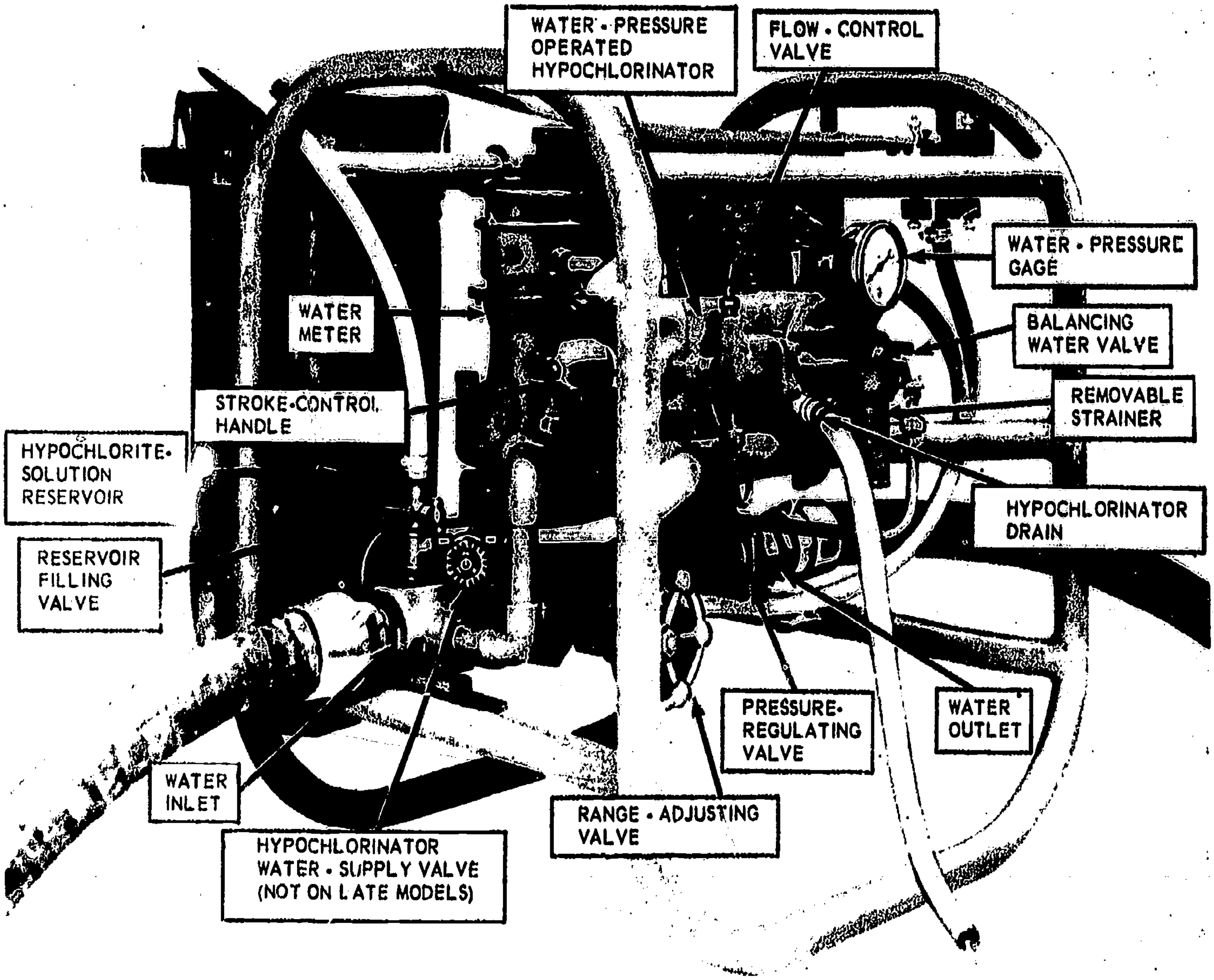


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Figure 7-10.—Portable automatic hypochlorination unit (left front view).

The unit is usually mounted on a pipe frame with skids. Its main parts are a hydraulically operated hypochlorinator, a water meter, a manual range adjusting valve, and a pressure regulating valve.

The hypochlorinator pumps the hypochlorite solution into the water at a rate governed by the speed of the water meter. The water meter is operated by a small flow of water which is diverted from the main line by means of the manual range adjusting valve. The water pressure regulating valve maintains a water pressure in the system of at least 10 pounds per square inch so that the hypochlorinator can be operated satisfactorily.

Operating Procedures

Before starting the hypochlorination unit, you should check it for any damage or leakage. Also check to make sure that there is an adequate supply of hypochlorite solution in the reservoir. If necessary, make up some new solution.

For a new solution, high test hypochlorite powder is added to clear water in the solution reservoir. If the maximum flow to be treated is near 100 gpm, add 10 ozs of hypochlorite powder to 5 gals of water. If you anticipate a maximum flow of 50 gpm, add 5 ozs to the 5 gals of water. If any extra chemical is left over, be sure that you store it in a dry, airtight container.

Now check the end of the hypochlorinator suction hose to see that the strainer is installed. Place the hose in the solution reservoir so that the strainer is at the bottom of the reservoir.

Your operating duties will be mostly valve adjusting. Set the hypochlorinator stroke control handle at 10 on the dial. Open wide the hypochlorinator water supply valve and the manual range adjusting valve.

Check to see that the water pressure gage on the hypochlorinator registers at least 10 pounds per square inch. See that the flow controller needle is open about 3/4 of a turn from its dead shut-off position.

Adjust the range adjusting valve so that the hypochlorinator runs at a speed of 12 strokes per minute when the maximum flow is reached. The maximum flow should not exceed 100 gpm.

Check to see that the hypochlorinator is primed. When properly primed, the hypochlorite solution should spurt into the sight glass during every suction stroke of the hypochlorinator. Usually the machine will be self-priming. The air vent on the sight glass must be closed when the hypochlorinator is running. If the unit cannot be primed, check the hypochlorinator suction line for air leaks.

After you have performed these operations, you will have little to do in operating the unit. Your chief duty will be to make up a new batch of hypochlorite solution whenever the level in the reservoir drops to within 2 or 3 inches of the strainer.

There are two things to consider in determining the amount of chlorine to be added to the water: one is the volume of hypochlorite solution used, and the other is the strength of the solution. For example, 60 gals of 0.5 percent hypochlorite solution contains the same amount of chlorine (2.5 lbs) as 30 gals of 1 percent solution.

If the volume of water being treated requires 2.5 lbs of chlorine per day, you may use either the 60 gals per day of 0.5 percent hypochlorite solution or the 30 gals per day of 1 percent solution.

At a speed of 12 strokes per minute, the hypochlorinator will pump 60 gals of solution per day when the stroke control handle is set at 10 on the dial. In general, it is more desirable to operate the hypochlorinator with a weak solution and a long stroke rather than with a strong solution and a short stroke. In the example, therefore, the 0.5 percent solution would be preferable.

If the water used to mix the sterilizing solution contains "hardness," it is advisable to add some soda ash to the solution. This will result in the precipitation of the "hardness" and the precipitate should be allowed to settle to the bottom of the reservoir. The amount of soda ash to use is best determined experimentally by observing the precipitate.

The shut-down of the unit is more or less automatic in that the hypochlorinator will stop when the water stops flowing through the main under treatment. Remove the hypochlorinator suction hose and strainer from the solution reservoir when you take the unit out of operation.

If the unit is to be removed for storage or shipment, or is to be exposed to freezing temperatures, all water must be drained from the hypochlorination unit. It is particularly important that all solution be drained from the hypochlorinator pumping block by removing the pumping block and poppet valves. The sight glass and solution reservoir should also be drained.

Maintenance and Repair

There is little to do in the maintenance field. No lubrication is required for this unit. While the machine is running, check the water pressure gage and the sight glass frequently. The pressure should not be less than 10 pounds. You should be able to see the solution spurt into the sight glass on every suction stroke of the hypochlorinator. At the first sign of failure, stop the unit and locate and correct the trouble.

Every few hours check to see that there is an adequate supply of hypochlorite solution in the reservoir. If necessary make up some new solution. Test the chlorine residual frequently.

After the unit has been shut down, make sure that the hypochlorite suction hose and strainer have been removed from the solution reservoir. If necessary, clean the strainer. Also examine the balancing water valve strainer and clean it if necessary. It is very important that the hypochlorinator be kept clean because chlorine is highly corrosive and calcium granules will plug feed lines.

TYPES OF DISTILLATION UNITS

Distillation is a method of changing water into steam by means of heat and changing the steam back into water by condensation. This process removes impurities and makes even sea water fit for drinking. The ultimate product resulting from condensation is called DISTILLATE.

Since distillation is an expensive process, it is used only when other methods of obtaining drinking water are not possible—for example, when the only available water supply is sea water.

In nature, distillation is carried out on a huge scale. Water evaporated from the surface of the earth is condensed in the cool atmosphere and is precipitated in the form of rain or snow. Science has benefited considerably from nature's method of distillation. Man could not live were it not for this distillation.

Theoretically, in compression distillation no direct heat is applied to the liquid except to start the process. The heat to continue the process is generated by compressing the vapor to a higher pressure and temperature and discharging it back to the heating element of the same distillation unit (still). Heat which is given up through the discharge of distillate, radiation, and other causes is replaced by utilizing the raw water taken into the system, a compressor, and auxiliary heat. The temperature in this process is indicated in degrees Fahrenheit, and the pressure in pounds per square inch (psi). Psi is measured on standard gages and is indicated 0 psig, 1 psig, etc. Thus, a reading of 10 psig indicates that the gage reads 10 pounds per square inch.

85 GPH DISTILLATION UNIT

The 85 gallon per hour (gph) distillation unit, model DVC-8, is one type of unit used by the Seabees. (See fig. 7-11.) It is skid-mounted and has an operating weight of 4200 pounds. Its overall length, height, and width are 90, 56, and 58 inches, respectively. Output is approximately 1 gallon of distillate for each input of 2 gallons of raw water. Operated according to instructions, this unit can run continuously, maintaining specified output for 720

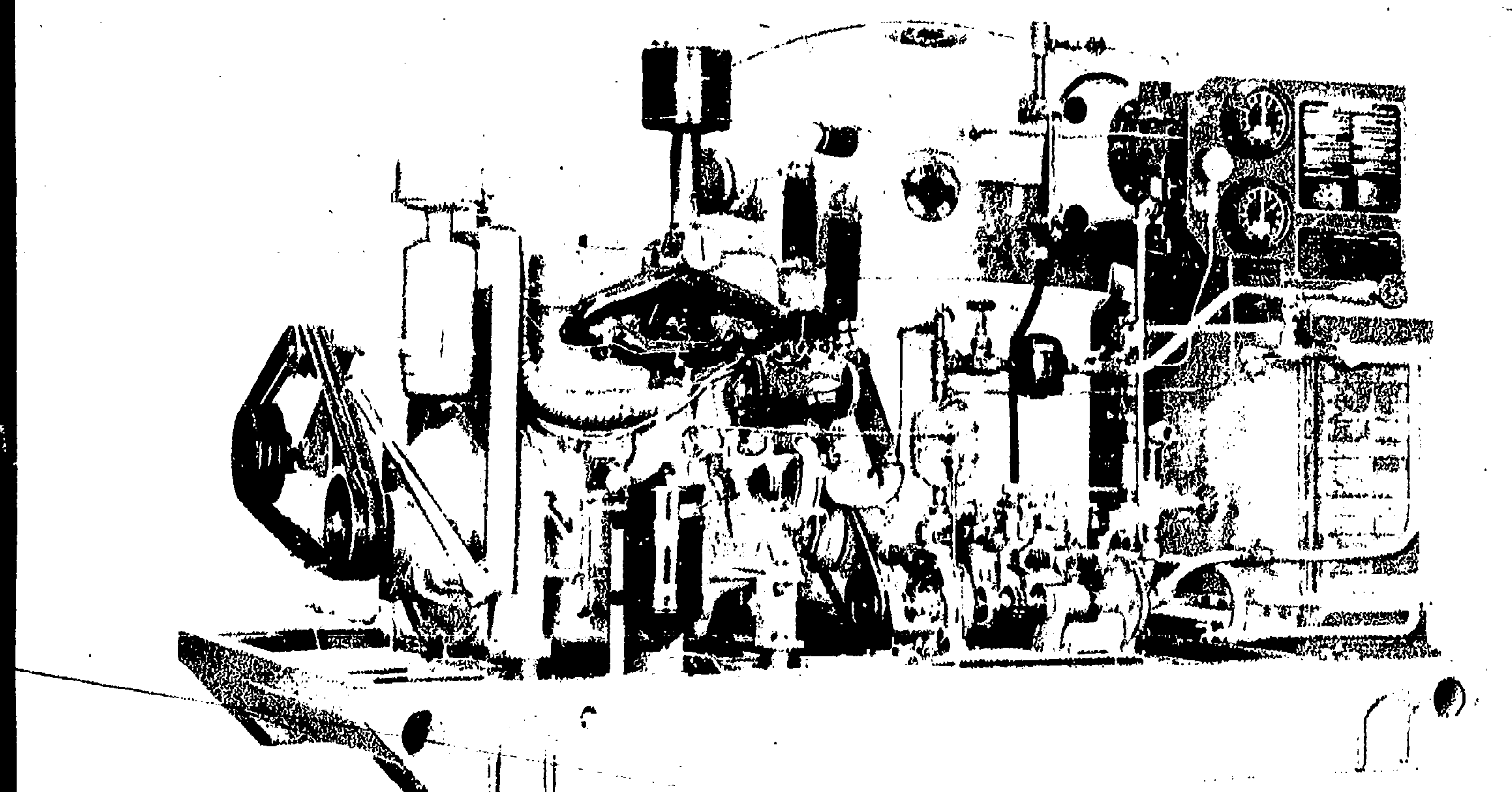

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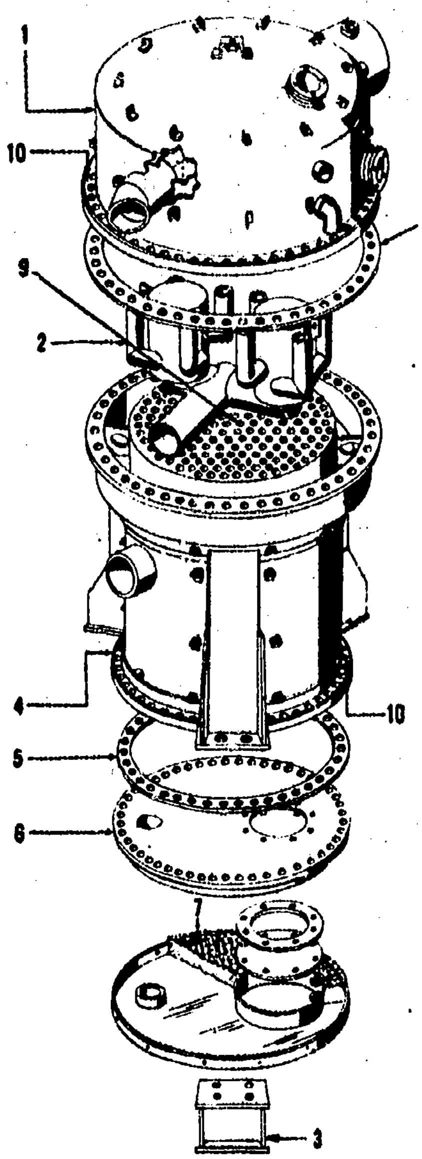
Figure 7-11. — 85-gph distillation unit, model DVC-8.



1. Vapor Head Assembly
2. Cyclone Steam Separator
3. Support, Evaporator
4. Evaporator Shell Assembly
5. Gasket, Bottom Head
6. Bottom Head
7. Insulation, Bottom Head
8. Gasket, Vapor Head
9. Tubes
10. Back-up Ring Top & Back-Up Ring, Bottom

54.92

Figure 7-12. — Evaporator assembly.

hours with short shutdowns for maintenance and lubrication.

Principal Components

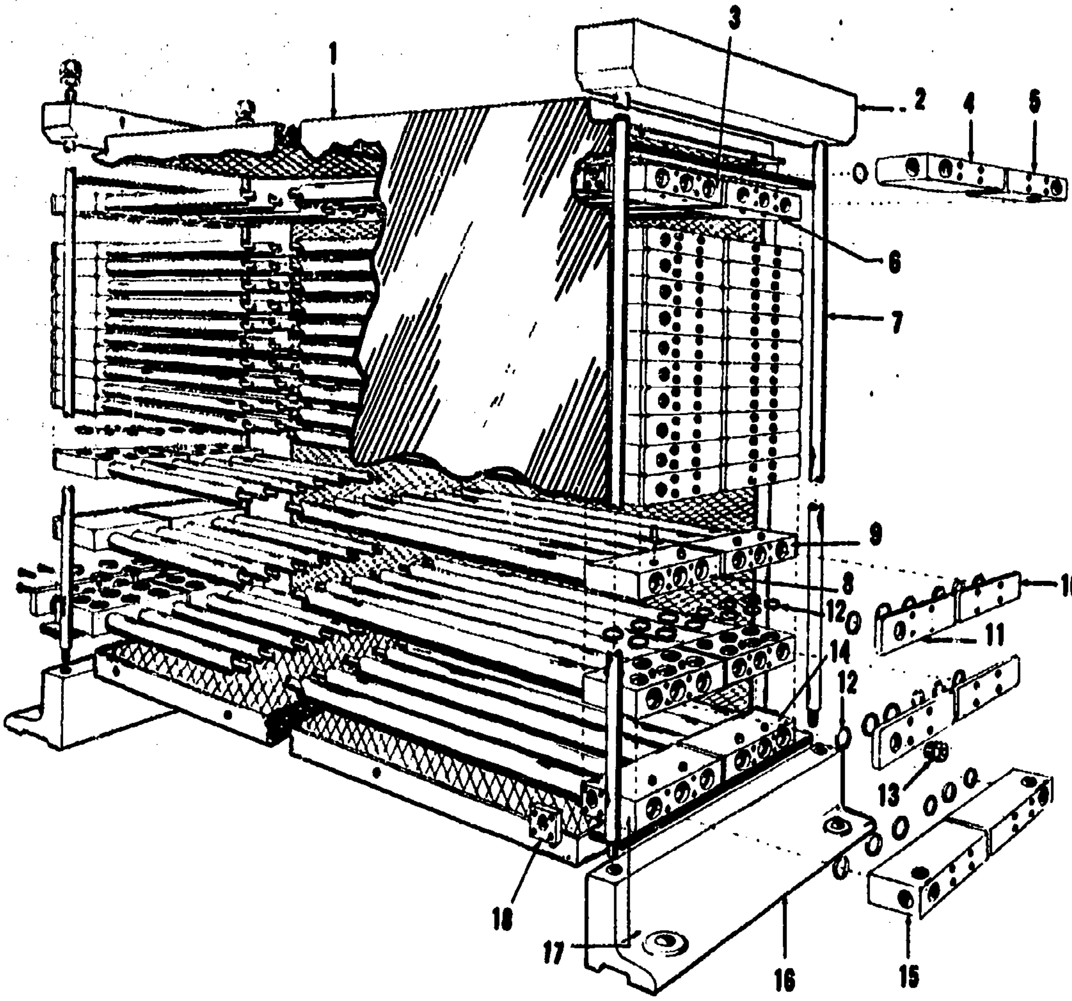
The essential components of the DVC-8 are: EVAPORATOR, HEAT EXCHANGER, VAPOR COMPRESSOR, DIESEL ENGINE, PUMPS, PIPING, GAGES, and CONTROLS.

The evaporator (fig. 7-12) furnishes the heat transfer surface in the form of tubes for vaporizing the raw water and condensing the resulting steam to form the distillate. Raw water in the tubes is brought to boil by external heat, thus producing steam which is recirculated back into the evaporator via a vapor compressor, where its temperature is increased. The steam condenses on the outer surfaces of the tubes, transferring its latent heat through the tube walls to the boiling water inside. The condensed steam collects on the bottom tube sheet, flows into the distillate line, then to the heat exchanger. Since the latent heat of the steam is recaptured in the evaporator and put to use boiling other water, only a small amount of additional external heat is needed to make up for the heat losses in the system. The evaporator consists principally of an evaporator condenser section (vertical tubes which provide the heat transfer surface), a vapor head (which incorporates a cyclone steam separator to separate entrained water particles from the steam), a bottom head (which serves as a storage well for the feed water), and various control devices such as a pressure gage, liquid level control, and gage glasses to indicate water level.

The purpose of the heat exchanger is to heat the incoming raw water so that less heat will be needed inside the evaporator, and the plant will be more efficient. (See fig. 7-13.) The sections in the heat exchangers consist of sets of concentric tubes. The raw water flows into the outer tube; blowdown or distillate flows within the inner tube.

The vent condenser (see fig. 7-14) also has two functions: (1) to remove noncondensable gases from the distillate, and (2) to reclaim some of the heat of the noncondensable gases and to transfer the heat to the feed water which flows through the internal tubes.

The vapor compressor draws the steam from the vapor head, compresses it, and forces it into the steam chest in the evaporator shell. This operation increases the pressure of the steam,



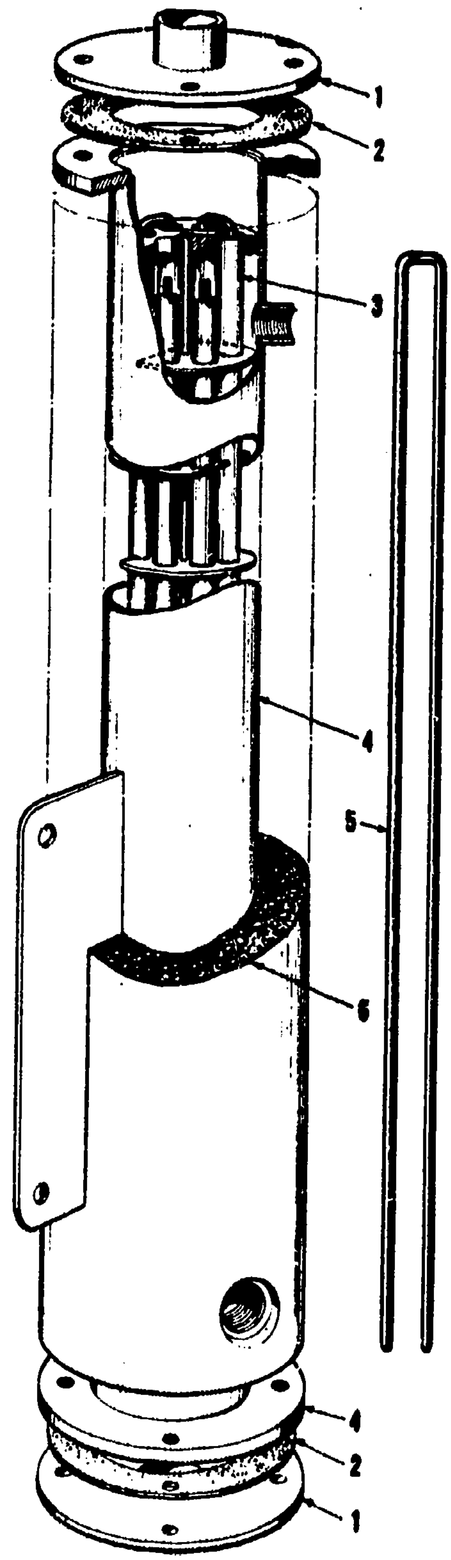
1. Jacket - Insulated
2. Bar - Tie
3. Section - Tube, Top Left
4. Cover-Distillate, Outlet
5. Cover-Blowdown, Inlet-Outlet
6. Section-Tube, Top Right
7. Rods - Tie
8. Section-Intermediate Tube, Left
9. Section-Intermediate Tube, Right
10. Cover-Blind
11. Cover-Distillate Bleeder
12. "O" Ring
13. Valve - Bleeder
14. Section - Bottom Tube, Right
15. Cover-Distillate, Inlet
16. Base
17. Section-Bottom Tube, Left
18. Adapter

Figure 7-13. — Heat exchanger. 54.93

thereby raising the steam temperature and adding to the latent heat of the steam the amount of heat necessary to vaporize more of the feed water in the tubes, thus inducing a continuous flow of steam through the compressor and back into the steam chest.

The diesel engine serves as a prime mover for the compressor and pumps; it also serves as the original source of heat which is controlled by setting valve D (fig. 7-15). Power from the engine is transmitted through sheave and belt drive assemblies. Follow the detailed instructions of the manufacturer concerning the method of starting and servicing the diesel engine.

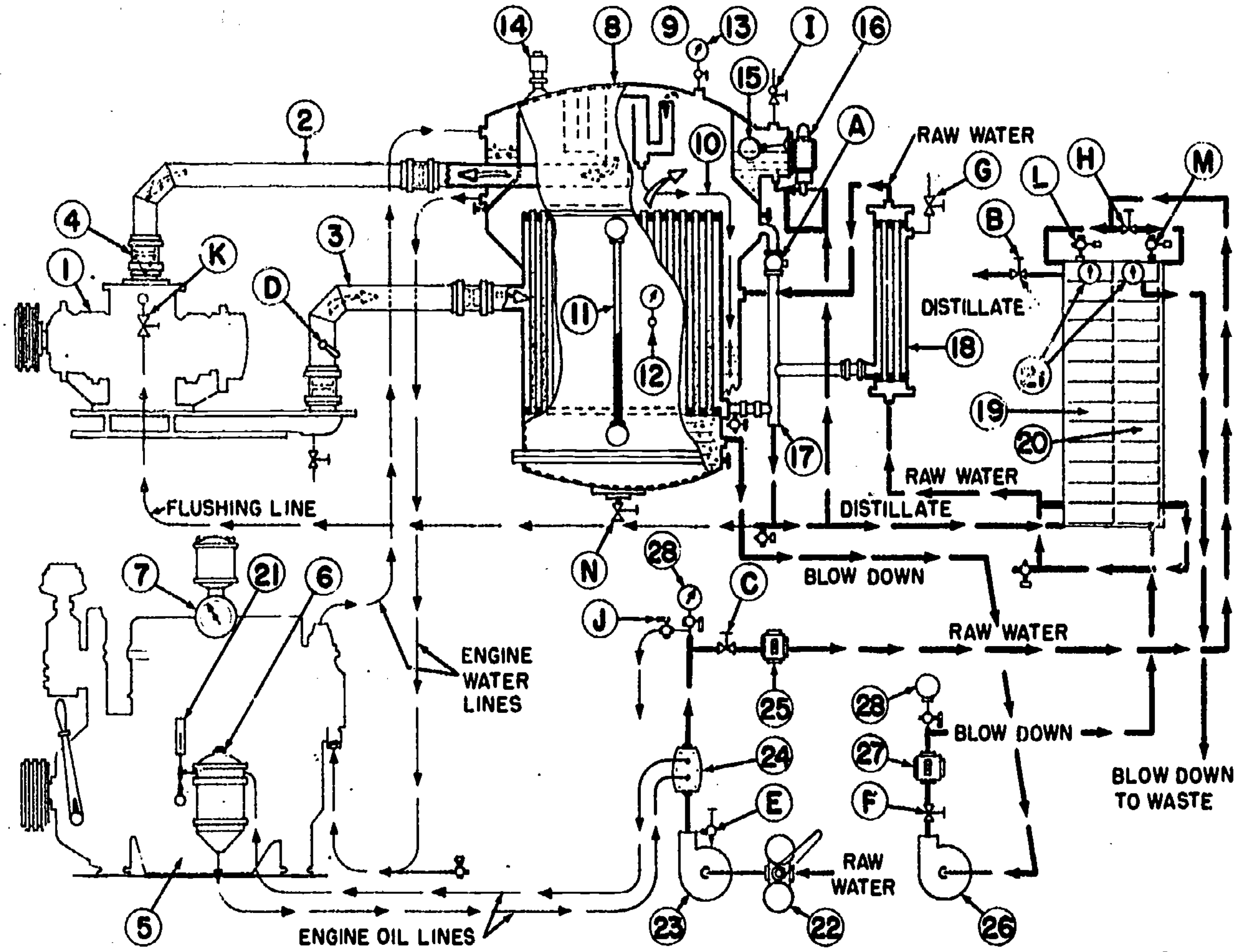
There are three piping systems in this distillation unit — raw water, blowdown, and distillate. Besides the pipes and pipe fittings, these systems consist of pumps, pressure gages, thermometers, flow meters, and various control and bypass valves.



1. Head Vent Condenser
2. Gasket Vent Condenser
3. Tube
4. Shell-Vent Condenser
5. Rod - Vent Condenser
6. Insulation, 1"

54.94

Figure 7-14. —Vent condenser.



Component Legend

1. Vapor compressor
2. Compressor suction duct
3. Compressor discharge duct
4. Steam strainer
5. Diesel engine
6. Oil filter
7. Thermometer
8. Evaporator
9. Steam separator
10. Drain tube-steam separator
11. Evaporator gage glass
12. Pressure gage-evaporator (steam chest)
13. Pressure gage-vapor head
14. Relief valve
15. Engine boiler
16. Water level control, engine boiler
17. By-pass line
18. Vent condenser
19. Heat exchanger-distillate-raw water
20. Heat exchanger-blowdown-raw water
21. Thermometers
22. Strainer-raw water
23. Pump-raw water
24. Oil cooler
25. Flow indicator-raw water
26. Pump-blowdown
27. Flow indicator-blowdown
28. Pressure gage-pump

Valve Legend

A. By-pass line valve
B. Distillate discharge valve
C. Raw water inlet valve
D. Compressor butterfly valve
E. Raw water pump by-pass valve
F. Blowdown discharge valve
G. Vent condenser vent valve
H. Heat exchanger by-pass valve
I. Engine boiler vent valve
J. Feed pump cooling valve
K. Compressor flushing valve
L. Heat exchanger distillate vent
M. Heat exchanger blowdown vent
N. Evaporator drain valve

54.95X

Figure 7-15. — Flow diagram, model DVC-8.

Description of Basic Flow

The three basic systems of flow — raw water, distillate, and blowdown — have separate flow cycles. The RAW WATER to be distilled enters the unit through the strainer, where suspended particles are removed. The pump, drawing the water through the strainer, pumps the raw water through the oil cooler, flow meter, and on into the heat exchanger. A pressure gage is located in the line beyond the oil cooler. The pump bypass line allows the liquid to be circulated about the pump when the main inlet valve is partially closed. There is another bypass line beyond the oil cooler to carry off coolant from the pump when the main inlet valve is closed. The flow meter registers in gallons per minute (gpm) the amount of water passing through it. A stop valve in the line immediately before the heat exchanger permits the raw water to circulate through the distillate exchanger or through both the distillate and blowdown heat exchangers.

All heat exchanger sections are made up of three tubes of intra-tube design (inner and outer). Only the headers differ. Looking at the unit from the engine side, as in the flow diagram (fig. 7-15) the distillate exchanger is on the left, and the blowdown exchanger is on the right. The raw water flows through the outer tube while the distillate or blowdown flows through the inner tube. In the raw water line from the pump there is a stop valve which permits control of the raw water to the distillate exchanger. This control is necessary during warm-up, to provide maximum heat savings, and during distillate production, in order to equalize distillate and blowdown temperatures.

The raw water enters both exchangers through the top sections, passing from the outer to middle to inside tubes, and then down through the header into the section below. The water continues to flow in this pattern until it is finally discharged from the outer tubes in the lowermost sections. From this point the flow passes through a vent condenser and finally empties into the evaporator. In the vent condenser, heat from noncondensable gases is transferred through the tubes to the raw water.

The level of the liquids is normally controlled by the raw water inlet valve. The level height is measured with the columnar sight glass on the side of the evaporator.

In the BLOWDOWN SYSTEM, the concentrated water and salt taken from the bottom head is known as the BLOWDOWN. This concentration must be removed to minimize the deposit of scale on the bottom head and evaporator tube surfaces. The blowdown is subjected to the pressure in the vapor head. After leaving the bottom head, the blowdown is pumped through a stop valve, which controls the amount of liquid through the pump, and into the heat exchanger. The flow enters the outside tube in the bottom section of the blowdown exchanger and is circulated in the same manner as the raw water (except that it is in the inner tube). After passing upward through the sections to the outside tube of the top section, the blowdown is discharged as waste. A thermometer on the front header of the top section indicates the discharge temperature.

In the DISTILLATE SYSTEM, the distillate, subjected to the compressor discharge pressure, flows from the bottom tube sheet into the hot well. Normally, the flow is direct to the heat exchanger. The distillate enters the outside tube of the bottom section and flows within the inner tubes to the outside tube in the top section in a pattern identical to that of the blowdown flow. A stop valve controls the distillate flow to storage. The thermometer in the outlet header registers the discharge temperature of the distillate. Some of the distillate will be required in two other locations: the engine boiler and the compressor. The engine operates with distilled water, except for emergency starting. A liquid level control acting as an automatic valve maintains the proper level.

The compressor will require occasional flushing with the distilled water to wash away any scale which may have been deposited on the rotors. The flushing valve is manually controlled.

Operating Instructions

The most important factor in the efficient operation of any distillation unit is to maintain the proper heat balance, which is the relationship of the amount of heat used to the amount discharged from the unit. If this requirement is met, the unit will operate at maximum efficiency. This means that a minimum amount of fuel oil will be required to produce distillate and that scale formation on the heat transfer surfaces will be kept at a minimum.

There are four mechanical components which require particular care. These are the engine, the compressor, the raw water pump, and the blowdown pump. The engine and compressor, in particular, require diligent care. Follow the instructions of the operating manual carefully.

PRECAUTIONS. — Observe the following precautions in operating the unit:

1. Drain the unit completely for long shutdown or when freezing may occur.
2. De-scale the unit when the difference in pressure between the evaporator gages reaches 5 psig, maximum 6 psig.
3. Do not start the engine unless the level gage on the engine boiler is full.
4. If the water foaming in the evaporator head causes a carry-over, reduce the operating level to a point where the carry-over stops.
5. If the engine boiler was filled with sea water, withdraw gradually from the drain at intervals during normal operation. The make-up valve will automatically dilute during distillate production.

PREPARING TO START. — Use the following procedure to start the unit:

1. Lubricate at all points (on the model DVC-8 fittings are marked with red).
2. Fill the engine and the compressor with lubricating oil to the proper level.
3. Fill the fuel oil tank.
4. Open the following valves: bypass line valve, feed pump cooling valve, raw water inlet valve, and compressor butterfly valve. The raw water pump bypass valve should be only partially opened.
5. Close the following valves: blowdown discharge valve, vent condenser valve, heat exchanger bypass valve, engine boiler vent valve, compressor flushing valve, heat exchanger distillate vent, heat exchanger blowdown vent, and evaporator drain valve.
6. Close all drains except the compressor base drain (which should be closed shortly after starting the compressor).
7. Check to be sure that all gage valves are open.
8. Clean both strainers and fill to top with water to prime raw water pump and suction line.
9. Remove the filling plug and fill the engine boiler to the top, using pure water if possible.
10. Check suction connections for leaks.
11. Check all sheaves and belts for tension.

WARM-UP CYCLE. — Use the following procedure for the warm up:

1. Place the throttle in mid-speed position.
2. Pull out on the ignition switch and push the reset button and the starter button. If necessary, hold the reset button until the engine oil pressure builds up.
3. When the engine starts, watch for build-up of oil pressure within 15 to 20 seconds. Warm up 3 to 5 minutes, or until exhaust reaches 250° F.
4. Engage the clutch to start the compressor.
5. Fill the evaporator until the level reaches the middle of the gage glass. Close the raw water inlet valve, maintaining the level as required. Maintain exhaust temperature of 500° to 600° F by adjusting valve D.
6. When the evaporator head gage reaches 0 psig, partially open the vent condenser vent valve.
7. Bring the evaporator head gage pressure up to 1 to 2 psig, then close the by-pass line valve and the feed pump cooling valve; open the blowdown discharge valve. (Distillate and blowdown production can be speeded up by using the vents on the heat exchangers.)
8. Close off the compressor butterfly valve (if additional heat is required).
9. Partially open the heat exchanger bypass valve when the blowdown flow starts. Equalize the heat exchanger thermometer readings by means of this valve.

DISTILLATE PRODUCTION. — When the distillate starts to flow, operate with 1 to 2 psig pressure in the vapor head. Maintain the normal evaporator water level by adjusting the raw water inlet valve and regulating with the raw water pump bypass valve. The flow meter for the raw water should read about 3 gpm. The flow meter for the blowdown should read 1 1/2 gpm. The vent condenser vent valve should normally be open about 1 to 1 1/2 turns.

SHUTTING DOWN THE UNIT. — To shut down, disengage the clutch, open valve A, close valves B, C, and F, open valve D and the compressor base drain — in that order. Allow the engine exhaust to cool to 300° F; then secure the engine and engage the clutch.

200 GPH DISTILLATION UNIT

The 200 gallon per hour distillation unit, model DVC-20, is similar to the model DVC-8 unit, but is considerably larger. Its overall length is 114 inches, width 73 inches, height 90 inches, and weight 9000 pounds. (See fig. 7-16.) Like the 85 gph unit, the 200 gph unit

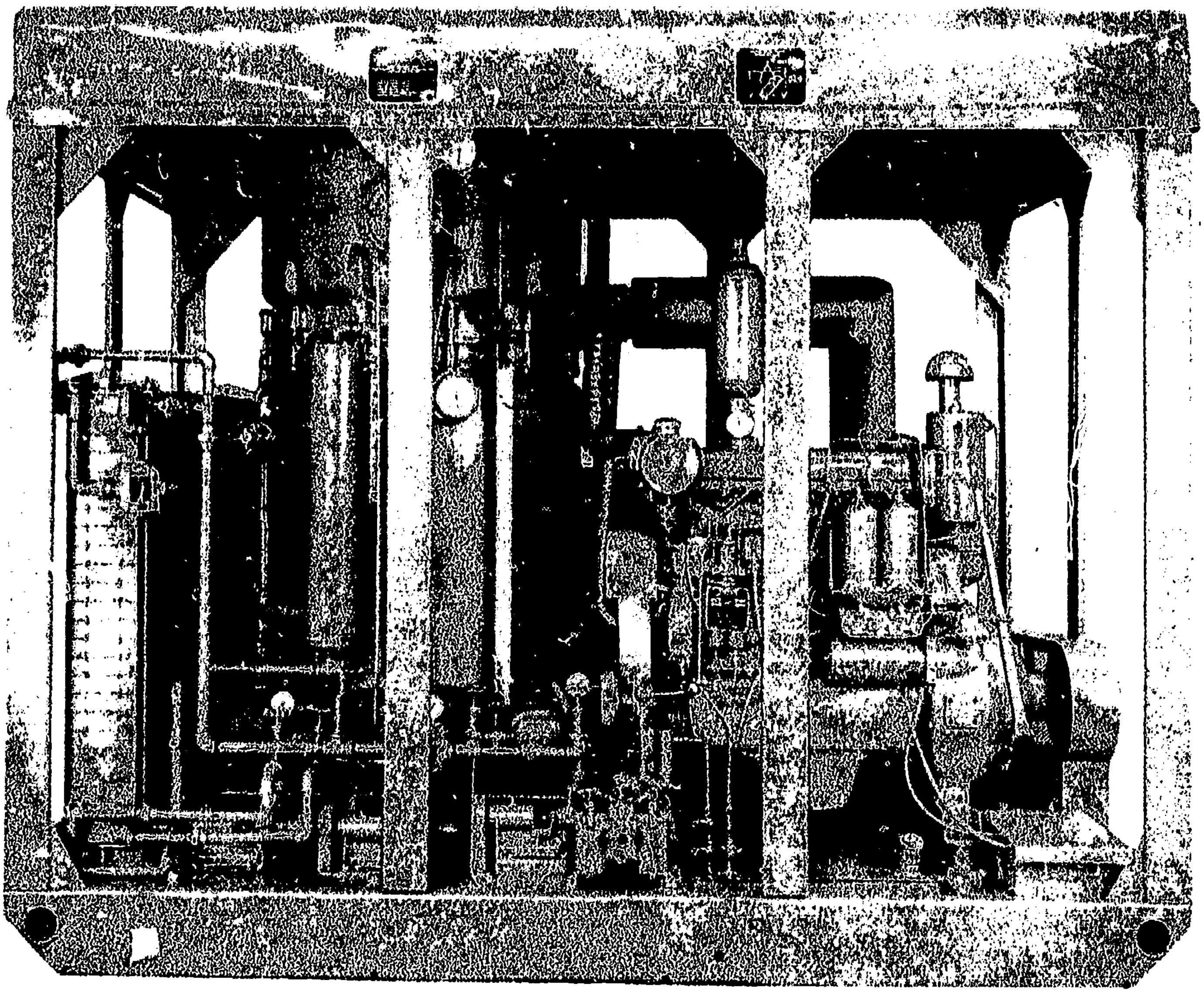


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Figure 7-16. — 200-gph distillation unit, model DVC-20.

produces about 1 gallon of distillate for each 2 gallons of raw water.

Basic Flow

The basic flow of the 200 gph unit is similar to the 85 gph unit. The raw water enters the unit through a strainer which removes suspended particles. The water then flows to the heat exchanger and from there to the vent condenser, from which it empties into the evaporator. In the evaporator, the raw water is first vaporized and then condensed. The fluid from the evaporator is discharged in two forms: blowdown and distillate. Blowdown is discharged as waste, while the distillate is stored for use. Both the blowdown and distillate are pumped through the heat exchanger to transfer their latent heat to the raw water.

Operating Procedure

The same precautions should be observed in starting the 200 gph unit as the 85 gph unit. Do not start the engine unless the level gage on the engine boiler is full and all moving parts rotate by hand. If the engine boiler was filled with sea water, withdraw gradually from the drain at intervals during normal operation. For long shutdowns, or when there is danger of freezing, drain the unit completely. De-scale the unit when the difference in pressure between the evaporator gages reaches 5 psig. Never allow this difference to exceed 6 psig.

PREPARING TO START. — Use the following procedure in starting the unit:

1. Lubricate at all points.
2. Fill the engine and the compressor with lubricating oil to the proper level.
3. Fill the fuel oil tank and the gasoline tank.
4. Open the feed water control valve, the evaporator bypass valve, the vent condenser vent valve, and the compressor butterfly valve.
5. Close the following valves: oil cooling water discharge, heat control, distillate control, blowdown control, bottom blowdown control, evaporator drain, heat exchanger bypass, oil cooler bypass, and compressor flushing.
6. Close all drains except the compressor base drain, which should be closed shortly after starting the compressor.
7. Check to see that all gage valves are open.
8. Clean both strainers and fill to top with water to prime raw water pump and suction line.
9. Remove filling plug and fill engine boiler to top, using pure water if possible.
10. Check feed water suction line for leaks.
11. Check all sheaves and belts for tension.

WARM-UP CYCLE. — Warm up the unit as follows:

1. Open the gasoline shut-off valve.
2. Pull the compression release lever all the way back to the gasoline (starting) position.
3. Place the engine speed control lever in the starting (shut-off) position and pull out on the ignition switch.
4. Depress the starter button and start the engine. (The engine should be operated on the gasoline cycle about 1 minute; 2 or 3 minutes in cold weather.)
5. Move the compression release lever forward to diesel position and immediately advance the engine speed control lever part way. Allow the engine to warm up.
6. Close the gasoline shut-off valve.
7. Engage the clutch to start compressor.
8. Adjust the engine speed control lever for 1350 revolutions per minute.
9. Fill the evaporator until the level reaches 10 inches in the gage glass.
10. Open the oil cooling water discharge valve.
11. Gradually close down on the evaporator bypass valve, maintaining a constant exhaust temperature until it is fully closed.

12. Adjust the vent condenser vent valve to partially open.

13. Open the distillate control valve as soon as suction pressure approaches zero or the condenser vent begins to emit water.
14. As soon as a steady distillate flow starts, open the feed water control valve to maintain the water level, and close the oil cooling water discharge valve.
15. Open the blowdown control valve.
16. If the feed water and air temperature are unusually low, it may be necessary to close down on the compressor butterfly valve to put more load on the engine, thus gaining more heat.

DISTILLATE PRODUCTION. — If the raw water temperature is between 45° and 135° F, the unit will produce distillate within 1 1/2 hours. When the distillate starts to flow, make the following adjustments:

1. Adjust the feed water control valve so as to hold 0.5 to 1.00 psig suction pressure, and gradually bring the flow up to 6.00 to 6.75 gallons per minute. If the lubricating oil temperature falls below 140° F, operate the oil cooler bypass valve in conjunction with the feed water control valve to hold the temperature between 140° and 160°. Low feed water and air temperature may make it necessary to keep the compressure butterfly valve partially closed.
2. As soon as the blowdown starts, adjust the heat exchanger bypass valve to equalize the heat exchanger thermometer readings.
3. Regulate the heat control valve to maintain 0.5 to 1.0 psig in the vapor head.
4. If the blowdown falls below normal (150 to 200 gph) because of excessive foaming or line plugging while using top overflow, supplement by taking blowdown from the bottom head.
5. Adjust the compressor flushing valve to give a reading on the Junior Flowrator of from 0.1 gpm at 3 psi differential pressure to 0.2 gpm at 5 psi differential pressure.

SHUTTING DOWN. — Use the following procedure to shut down:

1. Open evaporator bypass, vent condenser vent valve, butterfly valve, and base drain.

Table 7-2. — Trouble Chart for DVC-8 and DVC-20

Trouble	Probable cause
GENERAL	
Surplus heat	Low water level Scaling Compressor packing too tight
Lack of heat	Too low feed water temperature Too low exhaust temperature
Too low pH	Improper venting of evaporator shell
Too high conductivity	Overgreasing of feed pump Overgreasing of compressor Dirty or leaky exchanger Evaporator bypass valve not closing or seating properly
Difficulty in maintaining equal distillate-blowdown temperature	Equalizing valve out of adjustment
Low distillate production	Scale deposit on tubes Engine not at proper speed Improper venting Loss of steam through packing glands of compressor Leaks in tube sheets where they are expanded Evaporator bypass not closing or seating properly
Engine failure	Low water level in engine boiler Low lube oil pressure No fuel oil Air in fuel lines
EVAPORATOR	
High pressure in vapor head	Excessive engine exhaust temperature Butterfly closed in compressor discharge duct Low water level in evaporator Scaling of evaporator Improper venting Compressor packing too tight
Low pressure in vapor head	Butterfly open too far in compressor discharge duct Heat exchanger temperature gages not equalized Engine boiler vent valve or filling plug open Bypass line valve open
High pressure in shell	Scale deposit on tubes Insufficient venting of shell through vent condenser vent valve Faulty gage Low water level (supply pump not pumping or supply tank empty; hand valve not opening properly; obstruction in valve; dirty strainers)
Low pressure in shell	Compressor operating below rated speed Excessive clearance between lobes in compressor Distillate hot well drain valve open Evaporator bypass line valve open Faulty gage High water level (hand valve leaking or not closing properly)
High differential between head and shell pressures	Scale deposit on tubes Improper venting of air from shell Faulty gage Improper water level in tubes
Low differential between head and shell pressures	Leak in compressor seals Excessive clearance between compressor lobes Faulty gages
Failure to hold constant water level (within 1/2 in. variance)	Faulty level control Clogged raw liquid water strainer Failure of water supply

54.309.1

Table 7-2. — Trouble Chart for DVC-8 and DVC-20 — continued

Trouble	Probable cause
HEAT EXCHANGER	
Salinity condition in distillate	Leak through tube surface
	Leak in fitting or at tube sheet
	Carry-over of salt particles from evaporator due to high water level
Improper temperature relationship between the distillate discharge and raw water inlet	Scale deposit on tubes
COMPRESSOR	
Excessive bearing or gear wear	Improper lubrication
	Alignment
Loss of compressor efficiency due to leakage of steam	Improper clearance between lobes of compressor
	Improper clearance between lobes and casing
	Improper end clearance between lobes and casing
Noise in compressor	Oil level too low (improper oil; insufficient or improper grease)
	Water passing through lobes
	Friction of lobes with each other on the casing or the end plates
	Scale formation on lobes (can be removed by flushing lobes with distilled water)
BLOWDOWN PUMP	
No water delivered	Discharge head too high
	Impeller completely clogged
	Plugged blowdown valve or line
	Solids or dirt in heat exchanger
Not enough water delivered	Air leaks in suction pipe or stuffing box
	Leaky or plugged heat exchanger
	Discharge head higher than anticipated
	Impeller partially clogged
	Mechanical defects (worn or damaged impeller; worn casing)
Not enough pressure	Air in water
	Mechanical defects
Pump works for a while and then quits	Leaky suction line
	Water seal clogged
Pump takes too much power	Mechanical defects (bent shaft; impeller binds in casing; stuffing box packing too tight)

54.309.2

2. Reduce speed 1/3 on the diesel, allowing the engine exhaust to cool to 400° to 500° F.

3. Disengage the clutch and allow the engine to operate on the diesel until the exhaust temperature drops to 300° to 400° F.

4. Open the gasoline shut-off valve.

5. Simultaneously pull the compression release lever to the gasoline position and move the engine speed control lever to the shut-off position.

6. Allow the engine to operate on gasoline until the exhaust is clear; then close the gasoline shut off valve and the engine will stop. Place the compression release lever in the diesel position.

7. Close the feed water control valve, the heat control valve, the distillate control valve, the blowdown control valve, and the compressor flushing valve.

8. Fill gasoline and diesel tanks.

OPERATING TROUBLES

After the distillation unit (DVC-20 or DVC-8) is in operation, you will occasionally encounter operating problems. Operating troubles may be classified as: general, evaporator, heat exchanger, compressor, and blowdown pump. The first column of the trouble chart in table 7-2 lists common operating troubles. The second column gives the probable cause or causes of the trouble.

One of the most common operational difficulties is obtaining the proper rate of blowdown discharge. This is frequently caused by a clogged line or pump. To check for this operating trouble, remove the hose connection between the evaporator and the blowdown pump.

MAINTENANCE AND REPAIR

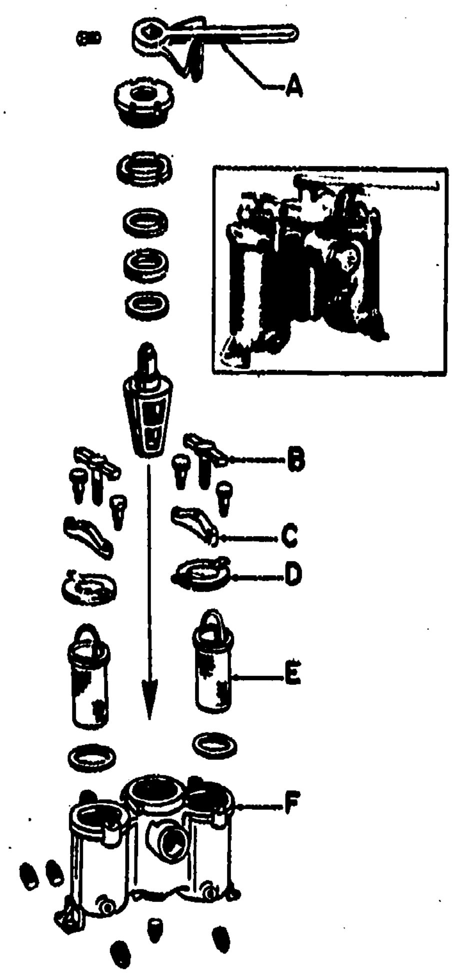
Both model DVC-8 and DVC-20 distillation units require a certain amount of maintenance. The maintenance may be divided into two categories: (1) normal servicing as necessary to assure efficient operation, and (2) checking of equipment at stated intervals, so that defects—if present—can be located and corrected.

Normal servicing includes cleaning, lubrication, and making simple adjustments. The diesel engine, fuel supply pump, compressor, blowdown pump, and raw water strainer are items which must be frequently cleaned or lubricated. The manual of operating instructions accompany a distillation unit explains the type of lubricant to use, frequency of lubrication, and manner of cleaning.

Inspection is an important phase of maintenance. Some equipment, such as the fuel supply pump and boiler level control, will require inspection and cleaning only twice or three times a year. Other parts of the unit, such as the generator, require much more frequent inspection. Any part of the equipment which becomes inoperative must, of course, be examined immediately.

Cleaning the Water Strainer

Raw water enters the unit through the strainer shown in figure 7-17. Maintenance of the strainer includes cleaning of the perforated baskets (E). The position of the handle (A) on the strainer indicates which basket is in use. The other basket may be removed by backing off the yoke screw and swinging the yoke clear of the basket cover. The basket is then exposed and may be removed from the body. Clean it by sloshing vigorously in clean water. Replace in the strainer body and lock in place by reversing the disassembly procedure. Set the strainer handle in the opposite position; the second basket may then be removed and cleaned.



A. Handle	D. Basket Cover
B. Yoke Screw	E. Basket
C. Swing Yoke	F. Body

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Figure 7-17.—Raw water strainer assembly.

The strainer may also need maintenance other than cleaning of the baskets. The valve can become frozen, clogged, or damaged. Covers can become damaged and gaskets lost or broken. The top of the valve stem should be marked as to direction of flow as the handle is sometimes put on in the wrong direction. The DVC-8 and DVC-20 are not marked clearly.

Removing Scale Formation

When a vapor compression distillation unit is operated at or near atmospheric pressure, certain chemical changes take place in the seal water which tend to cause scale formation on the heat transfer surfaces. If this scale deposit is allowed to build up, it seriously affects the performance of the still. One method which has been used successfully to prevent scale build-up in 200 gph distillation units is by acid cleaning. It is simple, safe to use, and effective over long periods of time.

In this method, the unit has been equipped with a special acid feeder pot which is installed as a bypass in the feed line just before it enters the evaporator. At prescribed intervals a charge of acid is injected into the evaporator. The amount added is sufficient to (1) neutralize the alkalinity in the sea water already in the unit, and (2) remove the thin film of scale formed since the last cleaning.

Experimental work has shown that an 8-hour interval provides good cleaning and is convenient from a scheduling standpoint. This time interval can be modified to suit the situation, but should not exceed 12 hours.

Cleaning is accomplished while the unit is "on the line." There is absolutely no danger of acid getting into the distilled water in a quantity that will be detectable. A vinegar and oil salad dressing is stronger than the acidified sea water and even if some of this sea water is carried over into the distillate, the water would be too salty to drink long before the acidity could be measured.

Any acid or acidic material which will dissolve in water can be used. The amount to use depends on the strength and can be determined by the method described later in this discussion.

From an economic standpoint, sulfuric acid (H_2SO_4) is the best. It can be used in concentrated form (1.86 sp.gr.) or the standard electrolyte strength (1.10 to 1.4 sp.gr.). Concentrated acid should be diluted 1 to 1 before being used in the unit. OBSERVE THE SAFETY PRECAUTION OF ADDING ACID TO WATER TO AVOID SPLATTERING. The electrolyte grade can be used full strength.

Where field conditions make the use of liquid acids inadvisable, crystalline acids such as suffamic, citric, or sodium bisulface (nitre cake) are recommended. Hydrochloric (muriatic) acid is not recommended because of its toxicity and greater corrosion effect on the metals in the unit. Several acids and the average dosage are listed in table 7-3.

Just prior to the time for cleaning, prepare the acid charge. A hard rubber bucket is excellent for this purpose, although any container will work. The following operation is performed while the machine is running:

Table 7-3. — 8-Hour Injection Schedule for DVC-20

ACID	BASIC DOSAGE
SULFURIC (Conc)	1 PINT
SULFURIC (Elect)	1 QUART
SULFAMIC	4 POUNDS
CITRIC	3 POUNDS
SODIUM BI-SULFATE	6 POUNDS

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1. Be sure bypass valve is closed.
2. Open acid pot.
3. Drain if necessary.
4. Add acid to pot.
5. Close cover securely.
6. Open bypass valve.
7. Close bypass valve in about 5 min.

During acid addition it may be necessary to open the vent valve to get rid of excess carbon dioxide (CO_2) liberated by the acid.

If instruments such as a pH meter are not available for determining dosage, the operator must rely on secondary effects which he can observe. It is important to record the evaporator pressures frequently. The difference between the condensing pressure and the evaporating pressure is a measure of the scale condition in the unit. As the scale increases, this pressure difference increases. It may take several days for a trend to become apparent. When such an increase is noticed, the acid dosage should be increased by as much as 50 percent. When the pressure difference stabilizes at some lower value, reduce the acid dosage by about 15 percent. Continue the trial and error adjustment until the optimum dosage is reached.

In addition to acid cleaning, scale may also be removed by mechanical means. A drill-type tube cleaner should be used for mechanical cleaning. Water lubricated drills having carbide tips work best. Shut down the unit and remove the vapor head. Chip the scale from the upper tube sheet, and proceed to clean the tubes in accordance with the instructions accompanying the tube drill. After finishing the chipping, flush the unit thoroughly from the top with a hose to remove all loose scale. The unit is ready for operation when the head is replaced.

OTHER DISTILLATION UNITS

The Seabees sometimes use distillation units other than the two described in this chapter. An 83 gph unit and a 150 gph unit, each using a gasoline engine rather than a diesel, are used at some bases.

The principle of operation for all compression distillation units is basically the same. If you have occasion to operate a unit other than the two just described, consult the manufacturer's manual describing the machine. The type of engine and the location of the parts may be different, but the operating procedure will be much the same.

AMMI FLASH DISTILLATION WATER BARGE

In a never-ending effort to obtain the best, and at the same time, the most efficient and economical equipment for support to military forces, the Navy has adopted a relatively new concept for purifying sea and/or brackish water. The unit in question has been tested in various parts of the world and has proven itself to be well qualified. Known as a LONG TUBE MULTI-STAGE FLASH EVAPORATOR, this water plant comes in a packaged, self-contained unit and consists of a diesel generator, a 300 hp boiler, an evaporator, and various control equipment mounted on an Ammi barge.

You may not have occasion to work with the long tube multi-stage flash evaporator (decal barge). Because of the importance of this equipment in the water treatment field, however, a brief discussion on it is given in this training manual.

THEORY OF OPERATION

The long tube multi-stage flash evaporator will produce distilled water from sea water by heating it until it is ready to flash. The flashed vapors are drawn to the cooler tube bundle surfaces where they are condensed and collected as distillate.

Flashing occurs when heated brine is turbulated in a chamber which is maintained at a lower vapor pressure than that of the entering heated brine. Heat is given up by the brine and a portion of it is converted into vapor until the temperature of the brine reaches the saturation temperature corresponding to the chamber pressure. In other words, the heated brine is flashed off by a pressure reduction instead of a temperature elevation.

Entrained brine droplets are removed from the vapors by stage de-misters and the pure vapors condense on the condenser tubes into distillate. The distillation process operates from a positive pressure in the first stage to a high vacuum in the last stage, with stage-to-stage pressure differential being the key to the repeated flashing.

Initial vacuum in the stages is created by a high pressure, steam-driven air ejector/condenser vacuum system.

The brine recirculation system is designed to operate at temperatures up to 250° F. In order to achieve long run operation of the unit, it is necessary to retard the formation of scale on heat transfer surfaces. This is accomplished through chemical treatment systems.

The brine recirculation system premits operation at higher evaporator temperatures and, at the same time, reduces the amount of feedwater chemical treatment required compared with that which would be required for once-through brine circulation operation at the same temperature.

PROCESS DESCRIPTION

Filtered raw sea water is pumped through the tubes of the last few evaporator stages and is discharged. The cool sea water flowing through the tubes dissipates the heat in those last stages and is called the heat rejection section of the plant.

A portion of this cooling water is withdrawn as make-up water and the main portion is returned to the ocean. The make-up water is deaerated to remove the noncondensible gases and is treated with sulfuric acid for scale and corrosion control purposes. The deaerated sea water falls into the brine section of the last stage and mixes with the recirculating brine flow. The mixture of recirculated brine and deaerated sea water is pumped through the tubes of the rest of the stages and the brine heater by the recirculation pump. These stages are termed the heat regenerative section of the plant.

In order to maintain a material balance in the system (controlling the brine density), a portion of the recirculated brine from the last

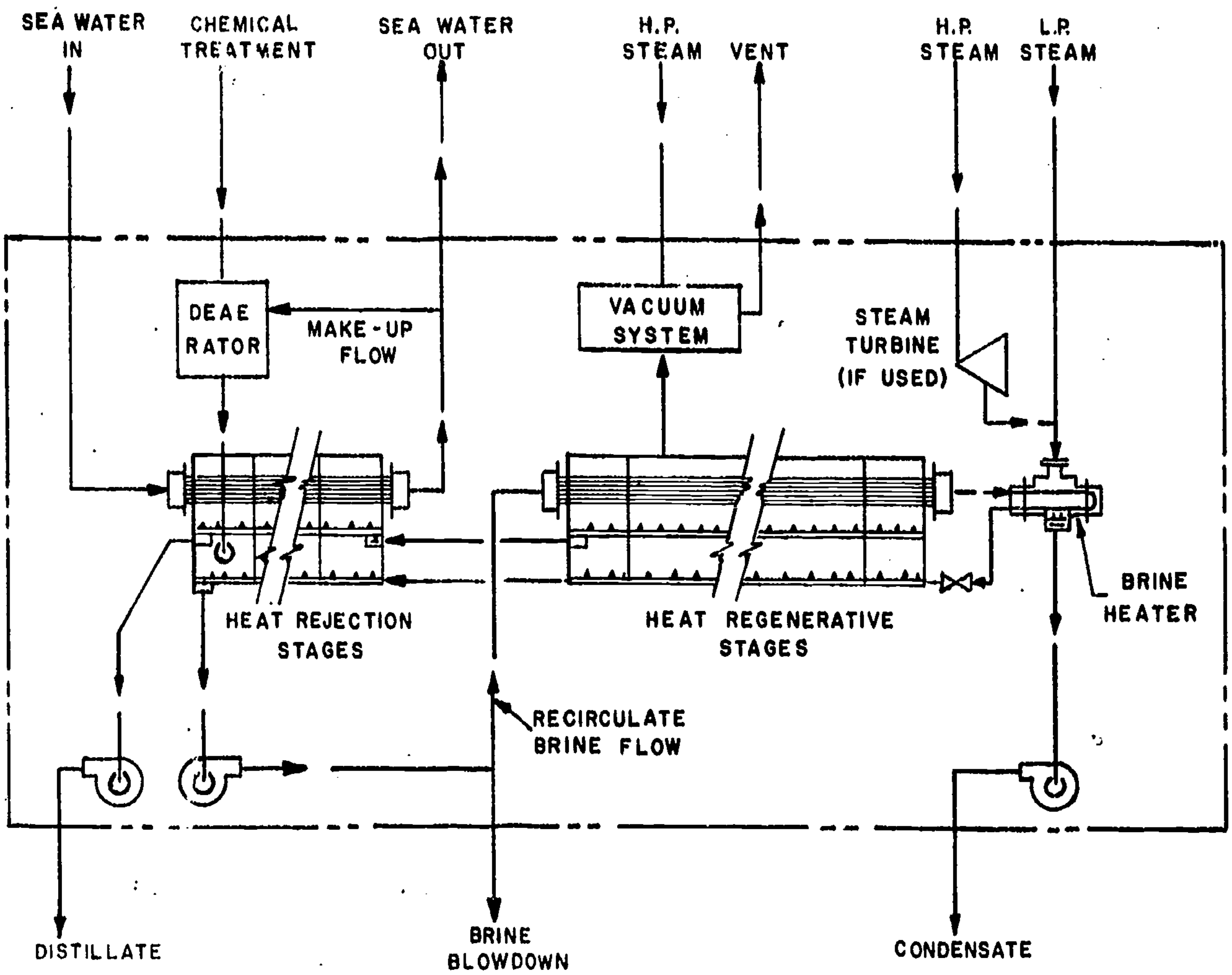

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Figure 7-18. — Flow diagram, long tube flash evaporator (brine recirculation system).

stage is discharged to the ocean. The blowdown flow rate is controlled by the brine level in the last stage.

As the brine flows through the condenser tubes of the heat regeneration section, it is progressively heated in each stage by flashing brine vapors condensing on the outer tube surfaces. The brine then passes through the tubes of the brine heater for final heating to its terminal temperature.

The heated brine is returned to the shell side of the first stage for flashing. The recirculating brine flows successively from the first to the last stage, flashing in each stage.

OPERATIONAL PROCEDURES

Once the diesel generator is on the line and supplying power to the plant, the boiler is fired and brought up to operating pressure. Upon attaining the proper amount of steam pressure, the sea water pump is started and pumps water from the ocean to the heat rejection section of the evaporator (see fig. 7-18). A portion of this same water is supplied to the condensers in the vacuum system for cooling purposes. Once this pump is in operation the valves controlling steam input to the air ejectors are opened and the ejectors start pulling a vacuum on the system. When the vacuum gage (manometer) indicates a reading approaching 22-24 inches of vacuum, the recirculating brine pump is started and establishes a consistent flow level through the evaporator stages. Once this level has been attained, steam is admitted to the brine heater through a pneumatically controlled valve. The amount of steam entering the brine heater and the amount of recirculating brine are gradually increased until the recirculating brine reaches its terminal or design temperature. At this time the vacuum should have reached its maximum value of 28 inches and the plant is in production with only minor adjustments remaining.

CONTROL SYSTEMS

There are four basic controls for the overall operation of the plant. These controls consist of:

1. A conductance measuring probe inserted into the distillate and the condensate water lines. These probes measure the specific conductance (in mhos) of the water and transmit these measurements to a solubridge (for the boiler) and a salinity recording meter (for the distillate). These instruments operate the necessary alarms and shut-off devices.

2. A pH metering system for the recirculating brine. This system is used for the control of scale build up in the brine heater and condensing tubes. The brine is passed over various electrodes located in a flow chamber. These electrodes measure the pH and transit measurements to a pH analyzer which, in turn, activates the high and low pH alarms.

3. A temperature transmitter which monitors the temperature of the brine heater and automatically adjusts the pneumatic valve which controls steam to the brine heater, thus regulating and maintaining a constant temperature in the brine heater.

4. Level trollers which are installed on the distillate and recirculating brine piping system. The controller for the brine system maintains, through a pneumatic valve, a predetermined brine level throughout the evaporator stages. The distillate controller maintains a proper level of water in the distillate trough by controlling two pneumatic valves. These pneumatic valves have solenoid valves in their air supply lines. These solenoids are electrically connected to the salinity recording meter. If the distillate salinity is below a set level, one of the pneumatic valves operates and allows the distillate to flow into storage tanks. If the salinity is too high, the other valve opens and discharges the impure distillate to waste.

CHAPTER 8

WATER TREATMENT PLANTS

After studying the previous chapters you know that treatment of water is necessary to prevent various water-borne diseases, such as typhoid and dysentery. You also know that certain chemical and physical characteristics of water — such as hardness or unpleasant tastes — must be controlled by treatment processes. Hence, the function of a water treatment plant is not only to make water safe for human consumption, but also to make water more palatable, less scale forming, and suitable for use in laundries, boiler plants and various other places.

In view of the scope of duties involved in water treatment plant operations, several chapters of this training course are used to cover various major topics of concern to the UT. This chapter discusses sources of water supply and some of the common types of equipment and treatment processes used at water treatment plants. The subject of clarification is discussed at length in chapter 9. Information on quality control in water treatment is provided in chapter 10. Chapter 11 deals with the maintenance of water treatment plant equipment and safety.

SOURCES OF SUPPLY

A satisfactory water source is one with a natural supply of water large enough to supply all needs of the users, and of such quality that it can be readily purified by available equipment.

At Navy activities the source of the water supply frequently is ground water or surface water. Ground water is obtained from such sources as wells and springs. Surface water comes from streams, lakes, rivers, and other such sources.

Ground water is oftentimes relatively free from contamination but for safety's sake should be given some treatment. If it is turbid, or brackish, purification is absolutely necessary. Surface water will almost certainly require treatment before it may be safely used.

At times treated water under pressure may be purchased from a nearby municipality or private water company. Additional pumping and minor treatment by the Navy is sometimes necessary with purchased water. On occasion, raw water may be purchased and fully treated by the Navy. A purchased supply of water may be augmented by ground water or surface water supplies, or used only as a standby for emergency use.

TREATMENT FACILITIES

Provisions for treating water vary from simple chlorination to complete plants for filtration and softening. The facilities available depend largely upon the character of the water supply. Chlorinators are a major type of equipment used in water treatment plants. The primary function of chlorinators is to feed chlorine into the water supply to disinfect the water, prevent minor recontamination, and control nuisance organisms in the distribution system. Aerators remove dissolved gases, principally hydrogen sulfide and carbon dioxide, and oxidize iron and manganese.

Filtration plants remove organisms, turbidity, iron, color, taste and odor from surface supplies and sometimes ground water supplies. Major units of a filtration plant include chemical feeders, chemical mixers, flocculators, sedimentation basin or tank, and rapid sand filters. Other main treatment units are scale and corrosion control feeders, lime softening plant, and zeolite softening plant.

CHLORINATION EQUIPMENT

Chlorination equipment used to feed chlorine gas or hypochlorite solution may be classified by type, depending on methods of control. Three methods of control are manual, semiautomatic, and fully automatic.

In the MANUALLY controlled type, equipment must be started and stopped manually, and the rate of feed must be manually adjusted to the rate of water flow.

In the SEMIAUTOMATIC type, equipment starts and stops automatically as water flow starts and stops, but must be manually adjusted to the rate of water flow. This type is normally used with water pumped at a fairly uniform rate.

In the FULLY AUTOMATIC type, the rate of feed is automatically adjusted to the rate of flow of the water being treated. The differential pressure of a metering device is used to accomplish this.

In all three types, the ratio of feed to water treated, or dosage, is set by manual adjustment.

Chlorinators may also be classified generally by type of feed. Here you have two types of machine — direct feed and solution feed. DIRECT-FEED machines are designed to operate without a pressure water supply, feeding the chlorine gas directly into the flow to be treated. SOLUTION-FEED machines dissolve the gas in a minor flow of water and inject the resultant solution into the flow to be treated. They require a pressure water supply for operation.

Another method of classifying chlorinators is by the type of diaphragm used in controlling the chlorine feed. There are two types — the water diaphragm and the mechanical diaphragm. The WATER diaphragm is always a vacuum type, solution-feed machine and has the advantages of being friction free and puncture-proof. The MECHANICAL diaphragm machine may be either direct- or solution-feed pressure type, or solution-feed vacuum type only.

DIRECT-FEED CHLORINATORS

Direct-feed chlorinators are used chiefly as emergency equipment and on small installations where it is not possible to obtain a water supply suitable for operating a solution-feed machine. They cannot be used where the pressure of the water being treated is more than 20 psi, and are limited in the types of semiautomatic and automatic controls which may be used. Because the chlorine is under pressure as a gas at all times, direct-feed machines are highly susceptible to the leakage of gas into a confined or poorly ventilated space, where it would result in corrosive action on adjacent equipment and structures. If you should be called upon to operate a direct-feed chlorinator, carefully follow the recommendations and instructions of the equipment manufacturer. You, as operator, must be thoroughly familiar with the equipment in order to ensure its proper operation, adjustment, and minor repair.

SOLUTION-FEED CHLORINATORS

A solution-feed type of chlorinator introduces chlorine gas into the water supply by means of a chlorine solution, usually formed by drawing chlorine gas into a jet stream of water at the low pressure point of an injector mechanism of the chlorinator. Two general types are used: (1) the bubbling or pulsating, reduced-pressure type, and (2) the vacuum type. Because the chlorine is kept under a partial vacuum, there are fewer chlorine leaks than with pressure gas chlorinators and direct diffusers.

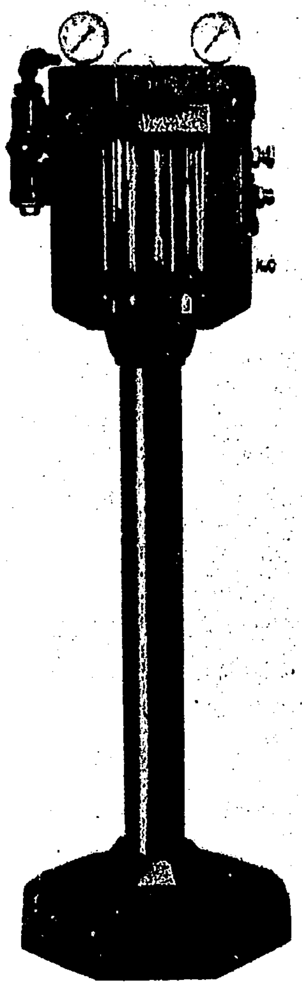

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Figure 8-1. — Pulsating type chlorinator.

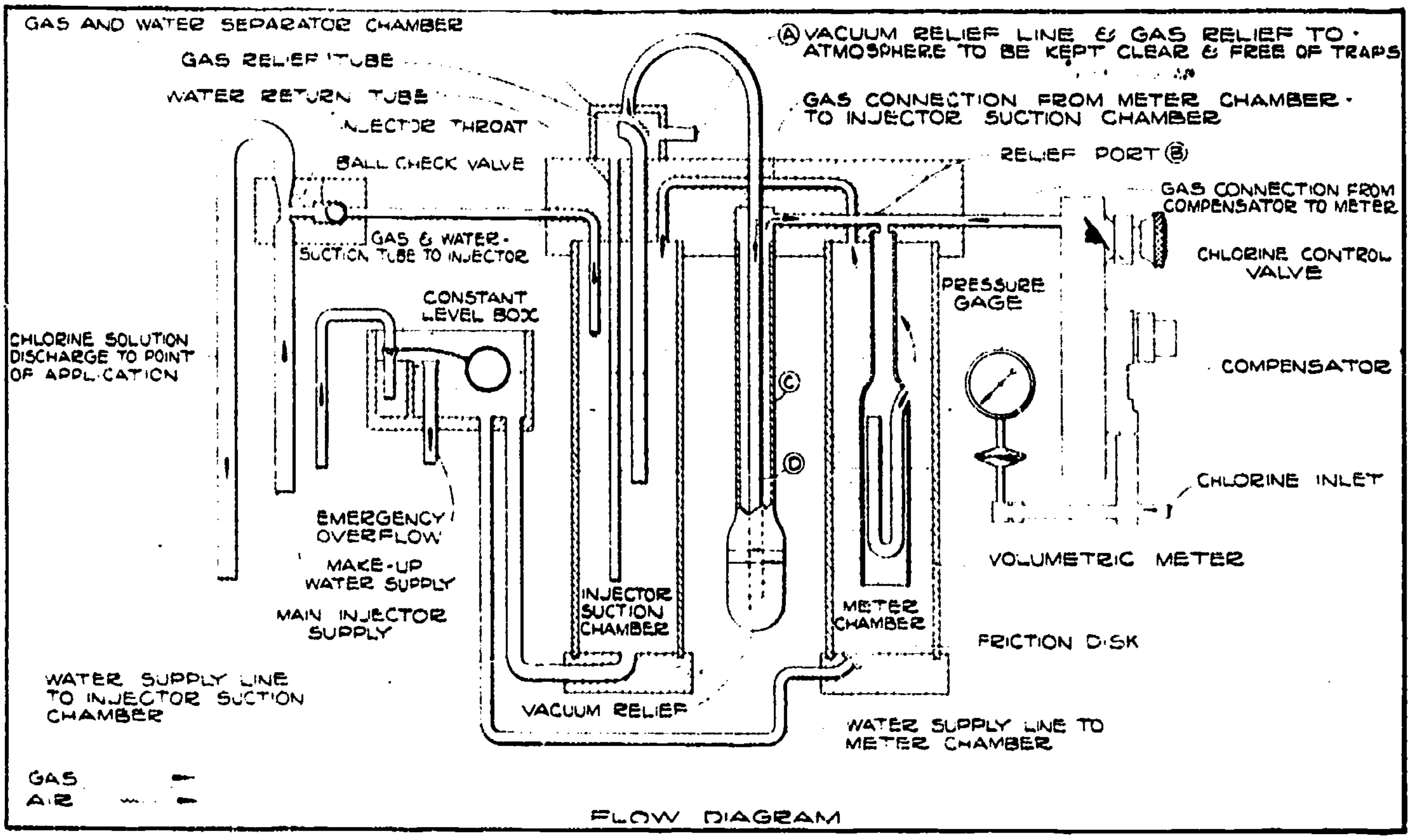

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Figure 8-2.—Flow diagram of pulsating type chlorinator.

Pulsating Type of Chlorinator

A pulsating type of chlorinator such as the one shown in figure 8-1 is suitable for small water supplies. A flow diagram illustrating the operation of a pulsating type chlorinator is presented in figure 8-2. Here in brief, is how it operates.

Chlorine gas flows from a cylinder through a compensator which adjusts the flow to a uniform rate, regardless of the cylinder pressure.

The gas then enters a volumetric meter, which is a submerged displacement siphon, and gradually displaces water until it escapes into the outer cylinder as a large bubble. The sudden release reduces the gas pressure within the meter, which again fills with water. The metered gas then passes into an injector suction chamber where it mixes with water.

Suction, produced by an injection throat, draws the chlorine solution into the discharge line, which carries it to the points of application.

The volumetric meter fills and empties at frequent intervals as the solution is applied to the water. The more rapid the pulsations, the greater the rate at which the chlorine is introduced into the water. The rate of feed can be determined by timing the pulsation and referring to the calibration table furnished with the machine. A needle valve controls the rate of pulsation.

A solenoid valve, which controls the water supply to the machine, can be actuated by the electric current of a pump to open the valve when the pump operates, and to close it when the pump stops, thus making the machine semiautomatic.

Vacuum-Type Water-Diaphragm Chlorinator

The vacuum-type water-diaphragm chlorinator has a bell jar set in a tray of water which acts as the water diaphragm. Observe figure 8-3, which shows a vacuum-type water-diaphragm chlorinator manufactured by Wallace and Tiernan, Inc. A flow diagram of this type of machine is presented in figure 8-4. A small quantity of water is constantly supplied to the tray to maintain the bell seal, and the excess overflows to waste. In some machines, this water is supplied

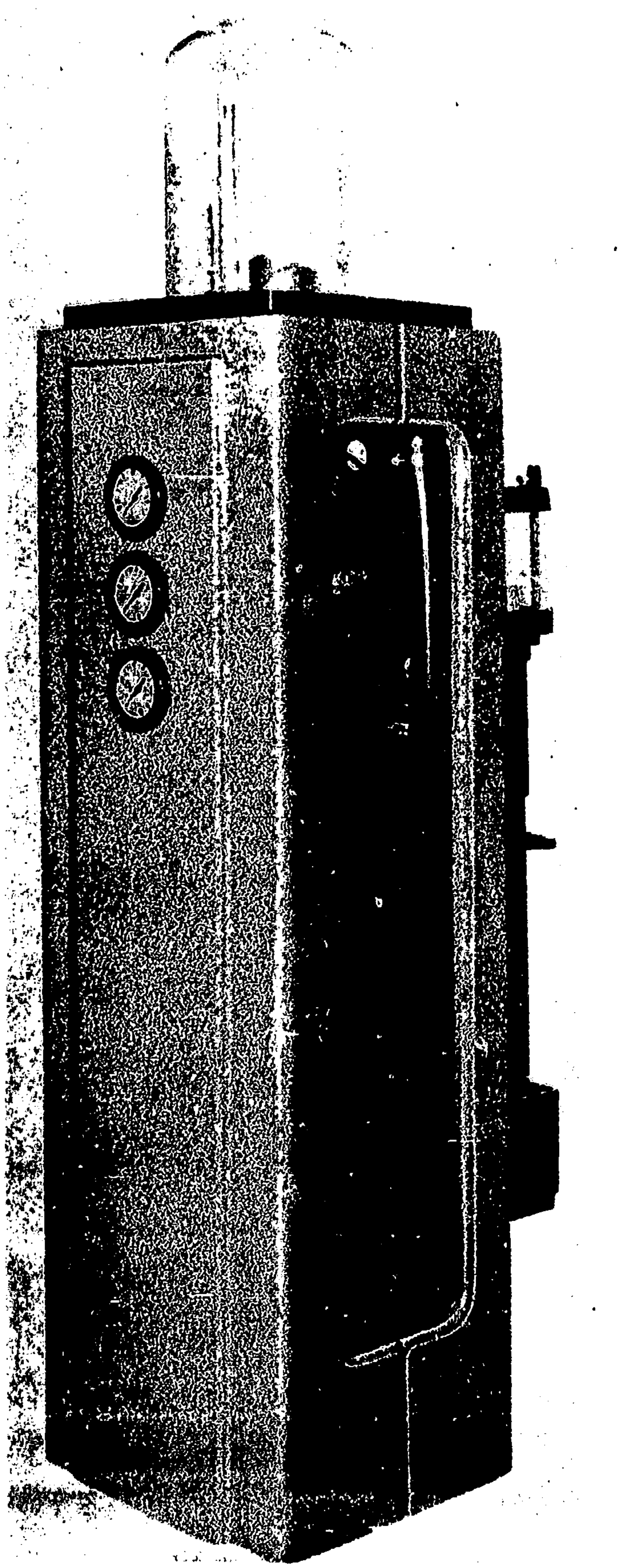

Figure 8-3. — Vacuum-type water-diaphragm chlorinator. 54.220X

through a constant-level box with a float-controlled makeup valve. The main elements of this chlorinator are the injectors through which a water supply flows; the chlorine control valve; and, the orifice meter. The injector creates a partial vacuum within the bell jar, thereby causing the water level to rise inside. Chlorine gas passes from the chlorine cylinder through the chlorine pressure-reducing valve and into the bell jar. The pressure-reducing valve is located inside the bell jar (see fig. 8-4) and is controlled by a ball-float which moves with the surface of the water within the bell jar. This inside water surface acts as a diaphragm. When it lowers, it causes the float-controlled valve to reduce the chlorine flow into the bell jar and, conversely, it increases the chlorine flow when the water level rises. The bell jar is also provided with a vacuum-relief valve to admit air when the chlorine supply is exhausted, or fails, and the water level in the jar rises. The metering orifice is also located inside the bell jar and above the water level. It controls the flow of the chlorine gas to the injector, where it is mixed with the water to be treated. The rate of feed is proportional to the negative pressure difference between the bell jar and the meter. The amount of vacuum within the meter is controlled by the height of the adjustable suction tube, and is indicated by the rise of water in the annular space within the glass meter tube. A scale mounted on the metering tube indicates the rate of chlorine feed in pounds per 24 hours. This machine can be equipped for manual, semiautomatic, or automatic operation.

Other Types of Chlorinators

In addition to the chlorinators discussed above, you may find various other types in use at naval activities. Among other types which may be available at your activity are the vacuum-type mechanical-diaphragm chlorinator, the volumetric vacuum-type chlorinator, the vacuum-type diaphragm-controlled chlorinator, and the V-notch vacuum-type chlorinator.

Regardless of the type of chlorinator, make sure that you follow the manufacturer's recommendations and instructions applicable to the operation and maintenance of the equipment.

HYPOCHLORINATORS

Hypochlorinators are solution chemical feeders which introduce chlorine into the water supply in the form of hypochlorite solution. They

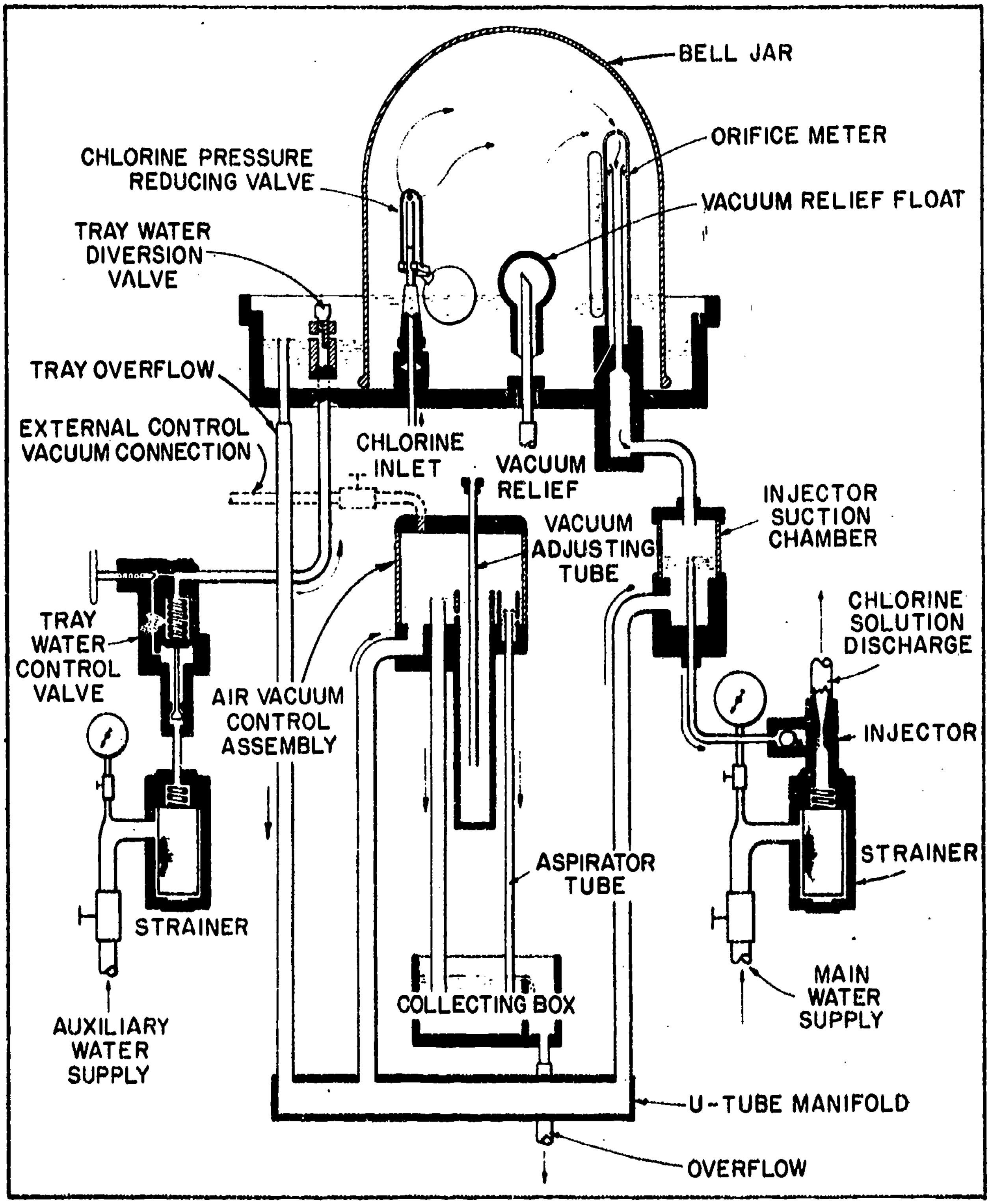

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Figure 8-4.—Flow diagram of vacuum-type water-diaphragm chlorinator.

are usually modified positive-displacement piston or diaphragm mechanical pumps. However, hydraulic displacement hypochlorinators are also used. Fully automatic types are actuated by pressure differentials produced by orifices, venturis, valves, meters or similar devices. Hypochlorinators are sometimes used as standby equipment for gas chlorinators. Portable equipment is also available which may be used for main disinfection or during emergencies. Hypochlorinators can also be used to feed chemicals for scale and corrosion control. You may recall that a portable automatic hypochlorination unit was described in the preceding chapter. Of course, you may have occasion to use various types of hypochlorinators. As part of this discussion on chlorination equipment, therefore, a brief treatment is given on additional types of hypochlorinators of interest to the Utilitiesman.

The Proportioneers Chlor-O-Feeder is a positive-displacement diaphragm-type pump with electric drive or hydraulic operating head. The electrically driven Proportioneers Chlor-O-Feeder is illustrated in figure 8-5. Maximum capacity of the most popular type, the heavy duty Midget Chlor-O-Feeder, is 95 gallons of solution in 24 hours.

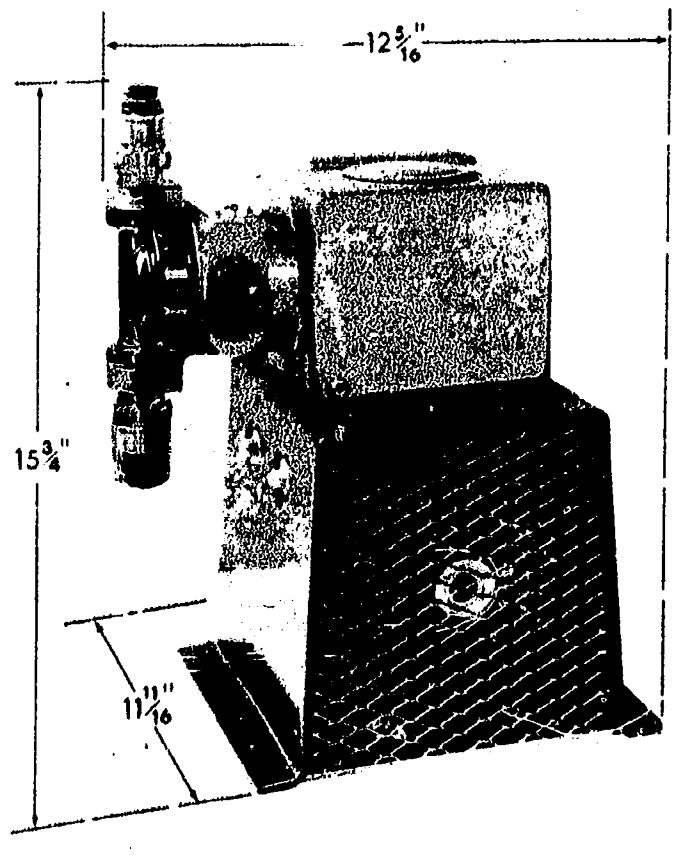

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Figure 8-5. --Electrically-driven Proportioneers Chlor-O-Feeder.

The motor-driven type of hypochlorinator may be electrically interconnected with the pump motor controls for semiautomatic operation (see fig. 8-6). The hydraulic type can be synchronized with pump operation by means of a solenoid valve.

Motor-driven types of hypochlorinator are made fully automatic by use of a secondary electrical control circuit actuated by a switch inserted in a disk or compound-meter gear box (see fig. 8-7). This switch closes momentarily each time a definite volume of water passes through the meter, thus starting the feeder. A timing element in the secondary circuit shuts off the feeder after a predetermined, adjustable number of feeder strokes. In the hydraulic type, the meter actuates gears in a gear box, which in turn controls operation of a pilot valve in the water or air supply operating the feeder. The dosage rate is controlled by water flow through the meter, thus automatically proportioning the treatment chemical. Opening and closing frequency of the valve determines the frequency of operation of the hypochlorinator.

Other types of hypochlorinator available include the Model S, which is manufactured by the Precision Chemical Pump Corporation. The Model S hypochlorinator is a positive-displacement diaphragm pump with a manually adjustable feeding capacity of 3 to 60 gallons per day. (See fig. 8-8). A motor-driven eccentric cam reciprocates the diaphragm, injecting the solution into the main supply The use of chemically resistant plastic and synthetic rubber in critcal parts contributes to long operating life.

LOCATION OF EQUIPMENT

It is essential that chlorination equipment be properly located with proper ventilation. All gas chlorinating equipment and chlorine gas cylinders, filled or empty, should be located in a separate room opening only from the outside, and should not be located in the same room or enclosure with operating equipment, other than equipment required for chlorination. If these conditions do not exist, take up the matter with your supervising petty officer. A typical chlorinator installation is shown in figure 8-9.

If the chlorination room is not located at such an elevation that the floor is level with or above the surrounding ground area, an exhaust fan (positive pressure blower type) should be

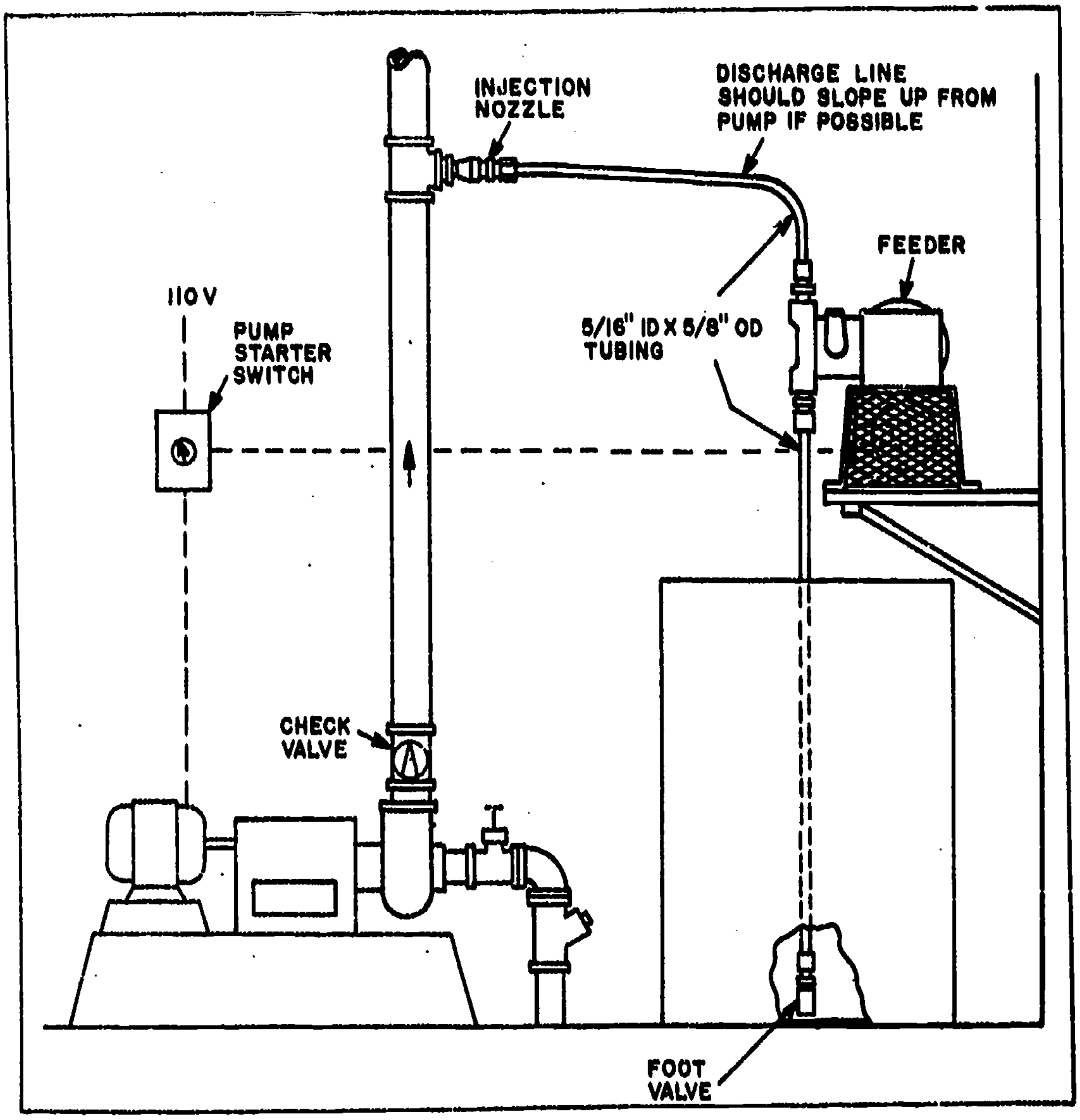

Figure 8-6.—Hypochlorinator arrangement. 54.223X

installed to remove gas or air at the floor level, and mechanical exhaust ventilation at floor level provided in any case. Doors should open outward, and two-way lighting switches should be provided both outside and inside the room. In case standard design conditions have not been met, get advice on what to do from your supervising petty officer.

It is normal practice to locate hypochlorinators in the same room with other equipment such as pumps, switchboards, meters and the like. However, due to the corrosiveness of the solutions, it is better practice to locate them in a separate room. If adequate floor drains have not been provided for waste water, spillage, sludge and washdown water, a 6-inch curbing should be provided around the entire area used for this purpose, whether in a separate room or in the same room with other equipment.

SAFETY PRECAUTIONS

Special care must be exercised in the handling of ammonia, chlorine and chlorine-yielding compounds. Properties that make chlorine difficult to handle include the following:

1. Chlorine gas is extremely irritating to the eyes, mouth, throat, and nose. Repeated exposure to relatively low concentrations may have a cumulative effect on the lungs. Because chlorine is heavier than air, exhaust ducts for venting fumes are installed to draw air from the lowest point in the room. The exhaust system blowers

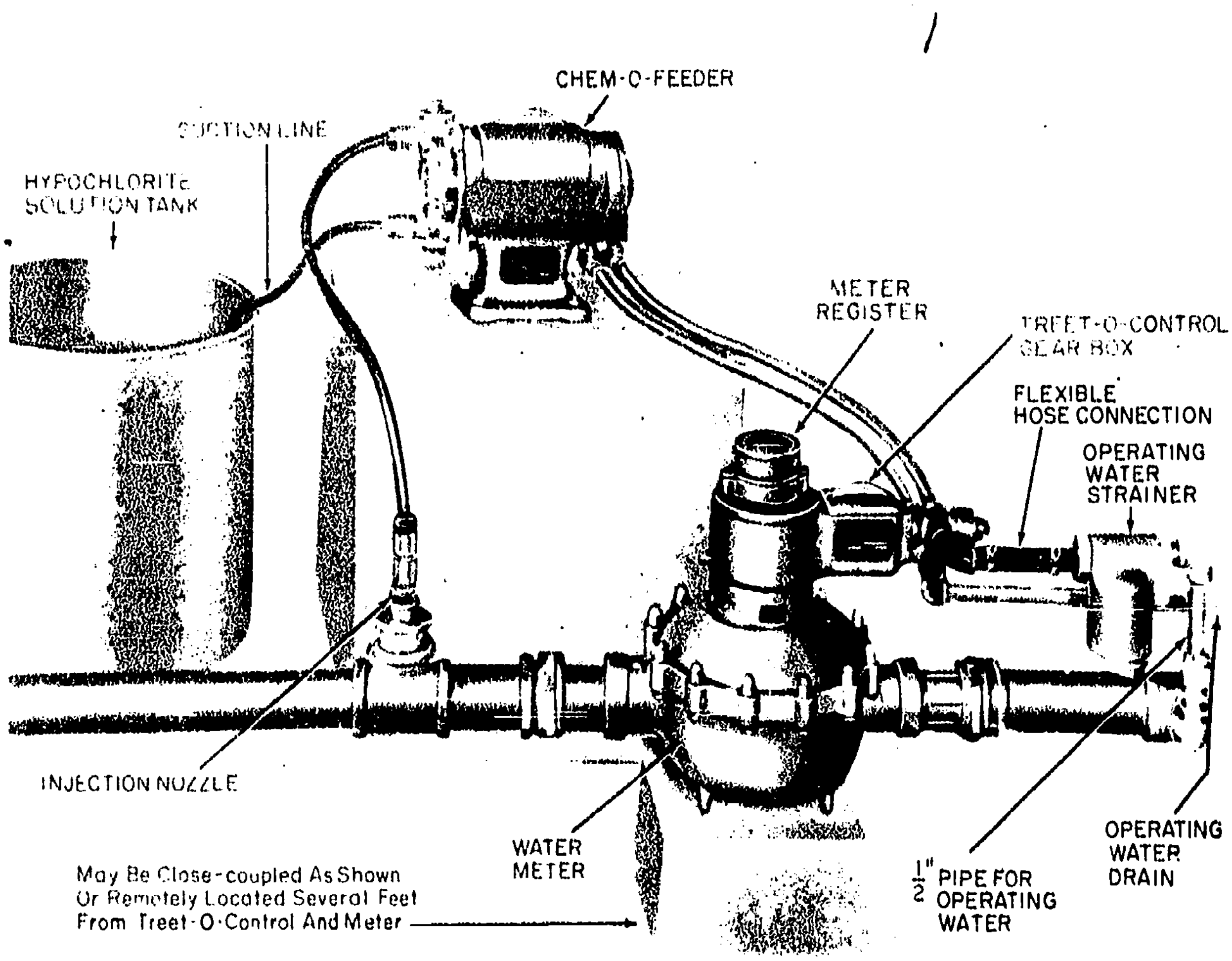

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Figure 8-7. — Motor-driven hypochlorinator with fully automatic control.

or fans must have their switches readily accessible from the outside.

2. Chlorine is noncorrosive when dry, but very corrosive when moist. Therefore, iron pipe can be used for dry gas, but parts coming into contact with chlorine solution must be made of silver, tantalum, glass, rubber or certain synthetic compounds.

3. Chlorine reacts with greases, oils, alcohol and ether to produce solid compounds which clog fittings and chlorinator parts. A Navy-approved cleaning agent should be used to remove these compounds.

4. High-test hypochlorites are relatively stable, but are extremely active oxidizing agents. If they come in contact with organic matter or other chemicals, they may cause an explosion.

Withdrawal of Chlorine from Cylinders

A cylinder received from the chlorine supplier may legally contain about 88 percent liquid chlorine by volume, and 12 percent dry chlorine gas at 79° F. Cylinder pressure keeps most of the chlorine in liquid form at ordinary pressures. When the cylinder valve is opened and gas withdrawn, the pressure in the cylinder is relieved and more liquid passes into the gaseous form. The change from liquid to gas requires heat that is absorbed from the surrounding air through the cylinder walls.

If gas is drawn off too rapidly, so much heat is taken from surrounding air that frost forms on the cylinder slowing gas formation. Maximum safe rates for drawing off chlorine are 400 pounds per day from a 1-ton cylinder, and 35 pounds per day from each 150-pound cylinder. Acceleration of chlorine gas withdrawal by heating the cylinders or placing them in a bath of hot water should not be attempted. This may melt the fusible plugs in the cylinders and allow the gas to escape. In addition, the hot iron of the cylinders can react with the chlorine.

Chlorine gas will change back to liquid in the piping between the cylinder and the pressure-reducing valve in the chlorinator if its temperature is reduced below that of the cylinder contents.

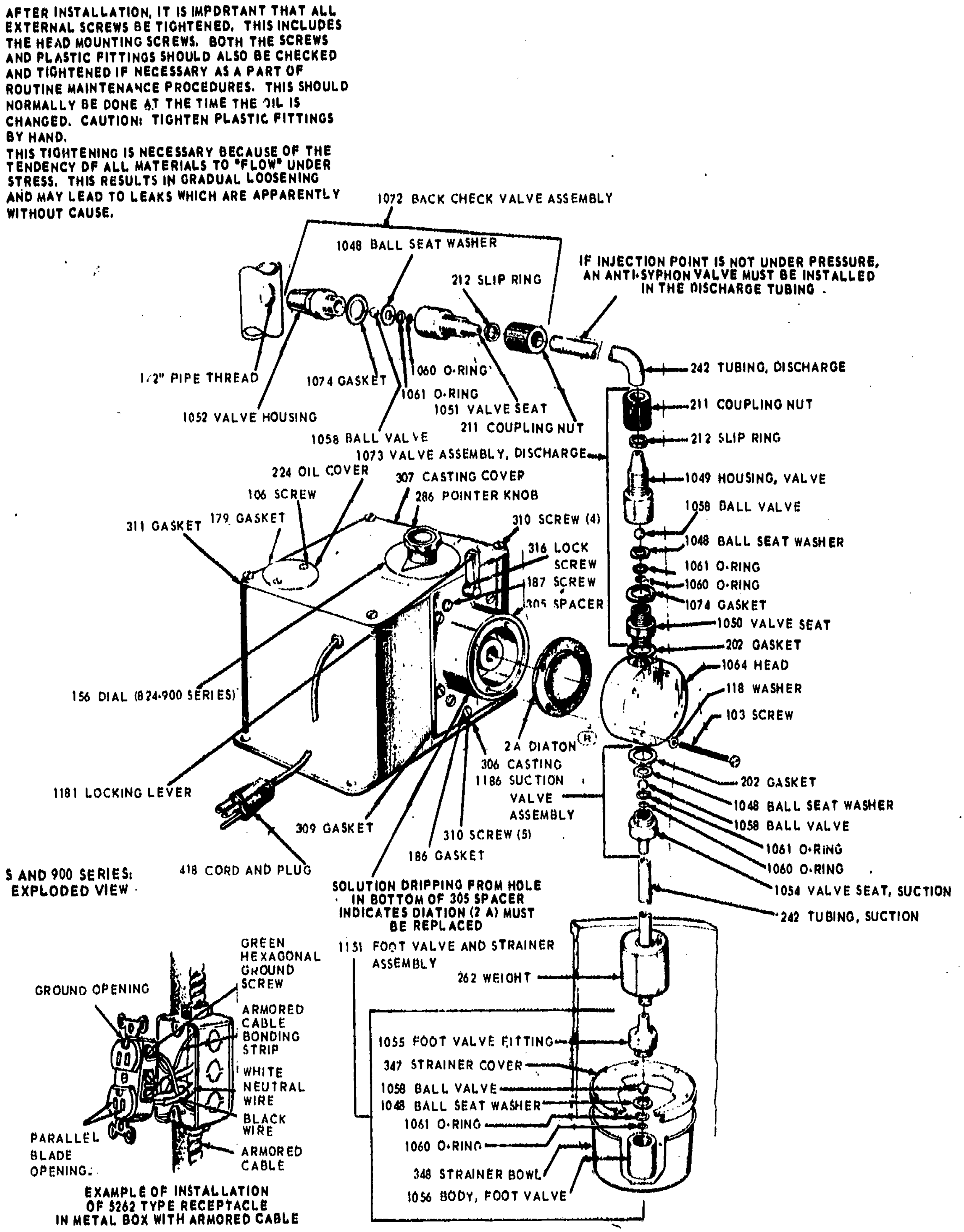

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Figure 8-8. —Model S hyphochlorinator.

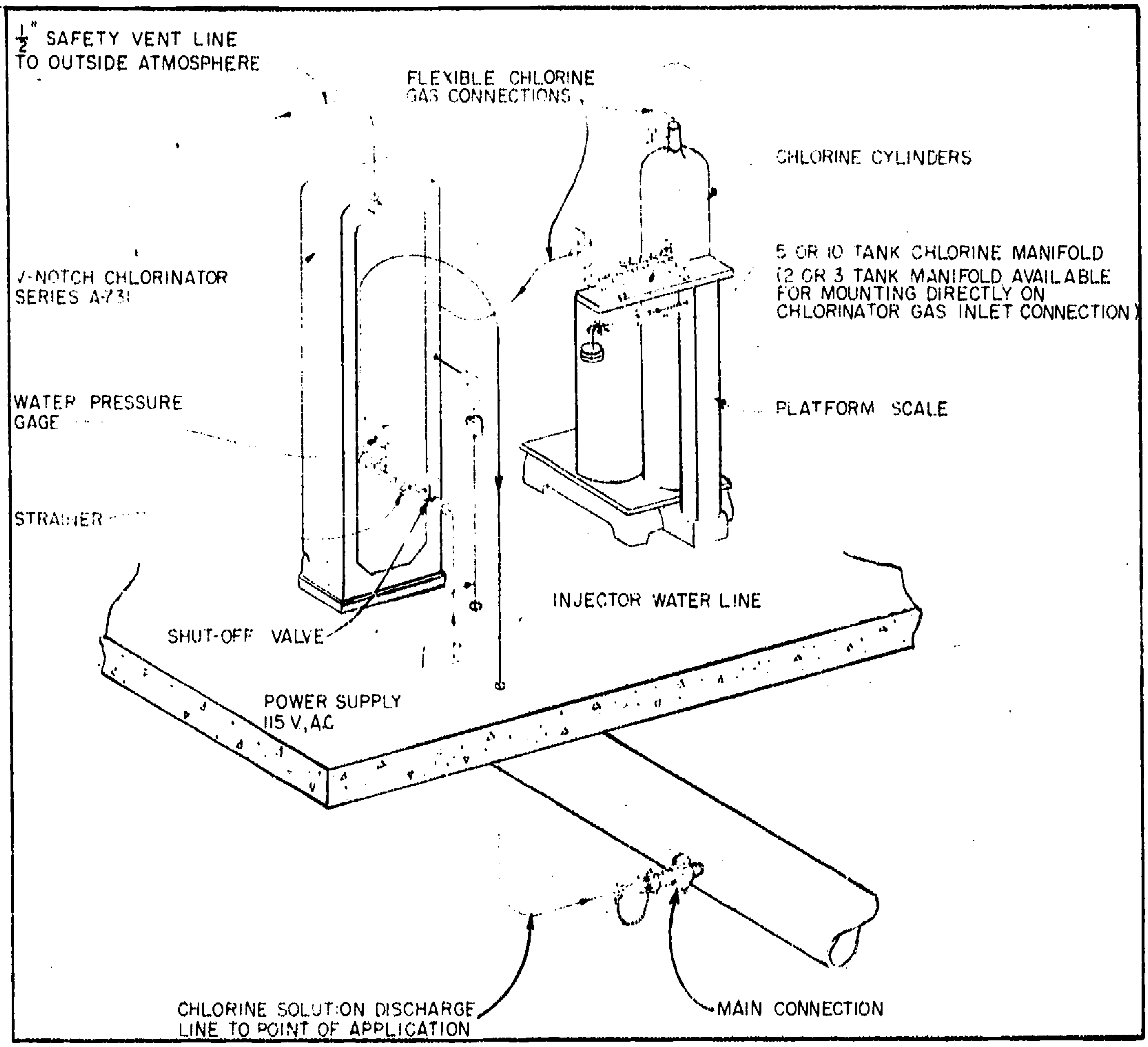

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Figure 8-9. — Typical chlorinator installation.

Such reliquefaction causes erratic chlorinator operation. To prevent reliquefaction of the gas, chlorine cylinders should be installed at points where their temperature will be the same or slightly lower than room temperature at the control unit. Avoid placing cylinders near heating units, in front of a window, or in direct sunlight. Do not allow cold drafts on chlorine pipe. If room temperatures are low and artificial heat is required to keep chlorine gas from reliquefying in the piping, limit temperature in the artificial heating unit to 100° F.

Chlorine hydrate, commonly termed "chlorine ice," sometimes forms within the chlorinator and interferes with operation. It is caused by low tray temperatures. If not severe, its formation can be prevented by hanging a 100-watt light bulb against the glass bell of the chlorinator. Otherwise, temper the tray water by using a hot-water coil or small electrical heating element which is available from the chlorinator manufacturer.

Use wrought iron, steel, copper or any other serviceable pipe to conduct dry chlorine gas from cylinders to chlorinator. Pipe must be extra-heavy type for 250-pound service, and at least 3/4-inch nominal size. Use a paste of freshly mixed litharge and glycerin to make up threaded joints; ordinary pipe dope cannot be used. Support piping securely. Slope it so that it drains back to cylinders without traps or snags, or provide drip legs at necessary sags to collect reliquefied chlorine gas. If room temperature does not vaporize condensate from a drip leg fast enough, shield the upper portion of leg with asbestos and warm the base with a permanently installed 100-watt light bulb.

Open chlorine valves slowly and carefully, using a wrench of proper size (not longer than 6 inches); never use an extension on the wrench. Open valves only part way; one full counterclockwise turn of the valve stem permits maximum discharge. Tap the wrench lightly to aid the operation of stuck valves.

Close the valves as soon as the cylinder is empty and mark a large "E" with a crayon on the cylinder near the valve. Return the empty cylinders promptly to the supplier.

Locating Leaks

Even small leaks can be detected because of the characteristically sharp chlorine odor. When a chlorine odor is noted, authorized personnel should start the ventilating system, put on self-contained oxygen breathing apparatus or self-generating oxygen breathing apparatus and locate the leak by holding an open bottle of ammonia water close to pipes, fittings, and valves. Ammonia vapor and chlorine gas form heavy white fumes, thus revealing the point from which chlorine is issuing. If the leak is in a line, shut off the flow of chlorine and repair the leak. If it is in the cylinder head and cannot be stopped by closing the valve, waste the gas from the cylinder outdoors in a good wind, or run it into a caustic soda solution. A solution of 25 pounds of caustic soda in 10 gallons of water will absorb 20 pounds of chlorine gas.

Hypochlorites

To prevent accidents caused by the corrosive action of hypochlorite solutions, use vitreous crocks or steel tanks lined with rubber or chlorine-resistant plastic as solution containers. Store calcium hypochlorite in a dry, cool location, and keep the cans sealed. Rubber gloves and protective aprons should be worn when preparing and handling hypochlorite solutions.

Ammonia

Ammonia fumes are poisonous, but even small concentrations of ammonia are quickly noticeable by its characteristic odor. Because the gas is extremely soluble, ammonia which has escaped can be picked up by a water spray. The same precautions used with chlorine are used in handling ammonia, with the following exceptions and additions:

1. Because ammonia is lighter than air, install vents at the top of the room.
2. Ammonia cylinders do not have fusible plugs because no fusible ammonia-resistant material is available. This presents an acute hazard because an ammonia cylinder filled to the legal limit becomes completely liquid at 145° F, and higher temperatures result in a buildup of hydrostatic pressure. Cylinders are tested at 700 psi under Interstate Commerce Commission regulations.
3. Test for leaks in ammonia gas piping with a bottle of dilute muriatic acid. White fumes form as with chlorine.
4. Ammonia solution or aqua ammonia can be stored indefinitely, but ammonia gas is evolved at about 80° F if the container is open. Store it in a cool place and keep the container tightly plugged. Dilute with cool water to 15 percent ammonia content before feeding. Keep the room housing the feeder well ventilated.

Sulfur Dioxide

Precautions in storing and handling chlorine also apply to sulfur dioxide (SO_2). Leaks are located with a bottle of ammonia water.

CHEMICAL FEEDERS

The quantity of chemicals added to the water must be carefully controlled to ensure uniform treatment. Many types of chemical feeders are available, but they can be divided into two major types—dry feed and solution feed. Because of the wide diversity of chemical feeders available, it is not feasible to describe individual units. However, you will be introduced to some of the common designs of chemical feeder. You are urged to consult the manufacturer's instructions and operating manuals for details concerning any particular make and model of feeder.

DRY FEED EQUIPMENT

A dry feeder measures out a uniform amount of chemical per unit of time and delivers it to a tank, where it is dissolved or dispersed before mixing with the water.

Type of dry feeder most suitable for a given application will depend largely on the amount of material to be fed per hour, and the nature of the material. A brief explanation will be given here on two types of dry feeding mechanisms — the disk type and the rotary feeder. If you are familiar with these types, you should have little difficulty following the manufacturer's instructions for other types which you may use in your work. Note that the dry feeding mechanisms discussed here may be controlled so as to feed by volume (volumetric) or by weight (gravimetric). They can also be automatically controlled to feed chemicals in response to demand, such as variation in water flow or pH. However, unless the savings in chemicals resulting from the greater accuracy of the gravimetric control warrant it, the smaller feeders are generally volumetric.

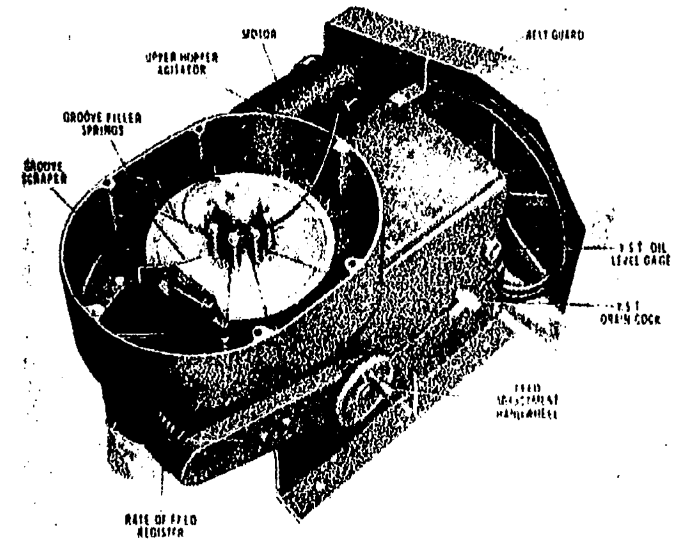
Errors in feeding dry materials are mainly due to the compressibility of the material being fed. It is evident that with a fluffy, compressible material, the weight being fed for a given displacement of the volumetric feeding mechanism will be greater when the hopper is full than when the hopper is nearly empty.

Disk Type

The disk type of feeder employs a rotating grooved disk and stationary plow for feeding (see fig. 8-10). The grooved disk is probably the most accurate of all continuous volumetric feeding mechanisms for small quantities of dry materials because the measuring groove in the face of the disk is machined to a known capacity per unit of length. The groove is filled and struck off level with the surface of the disk as it emerges from the hopper. The stationary plow is shaped to fit the groove with a close tolerance and practically all of the material is removed from the groove as it revolves.

The amount of material delivered is directly proportional to the number of revolutions made by the disk. With this type of feeder, various groove sizes are available having capacities up to a maximum of 400 ounces (25 lbs) per hour. A downward adjustment range of approximately 100 to 1 is obtainable through a variable speed drive. The maximum feed rate given above is based on 150 rpm of the disk and material weighing 65 pounds per cubic foot.

With a shallow hopper and noncompressible material, accuracy will be well within ±1 percent by volume, or ±3 percent by weight. The disk feeder is suitable for such water treating chemicals as hydrated lime, soda ash and activated carbon; and for average feeding rates of 10 pounds per hour. Where higher rates of feed are desired,



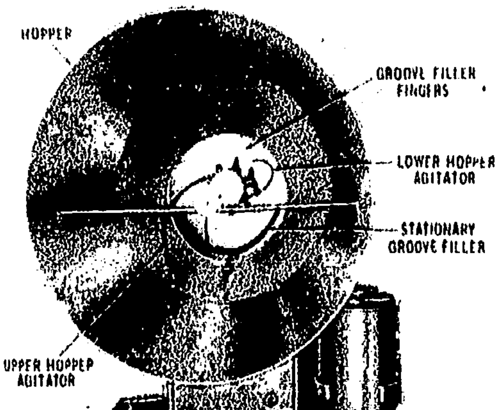


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Figure 8-10. — Disk-type chemical feeder.

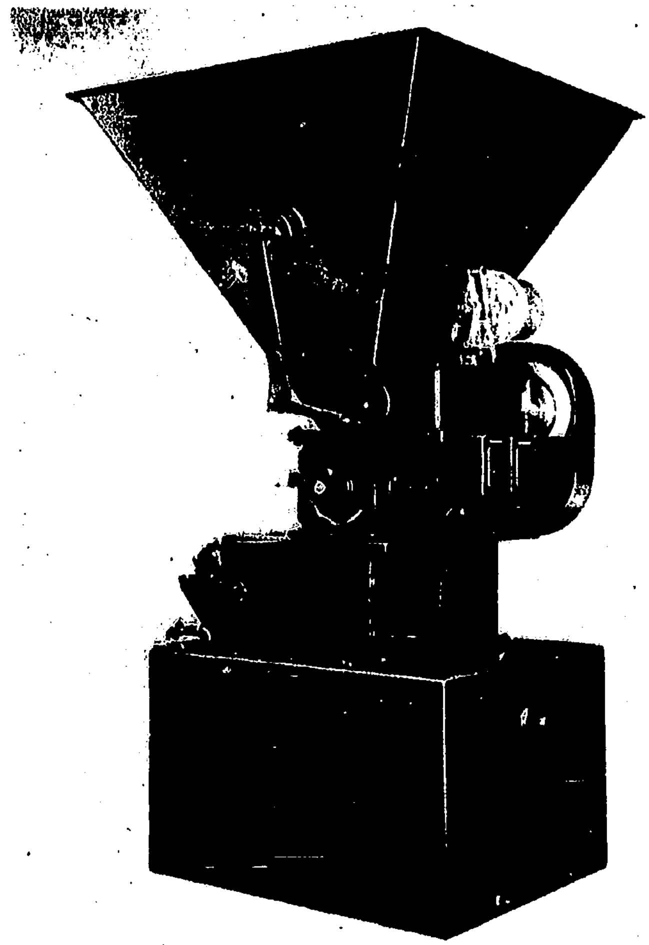

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Figure 8-11.—Rotary gate chemical feeder.

the groove is omitted and various widths of plows or spiral openings are inserted between the plate and the underside of the hopper to pull more or less material off the edge of the disk. Either of two methods is generally used; the first is to adjust the orifice by positioning a knife, and the second is to use a fixed plow and to vary the speed of the disk. The accuracy of this latter type feeder is within ±5 percent by volume.

Rotary Gate Feeder

The rotary gate (or star) chemical feeder is suitable for feeding rates of from 200 to 500 pounds per hour of material with free flowing characteristics (see fig. 8-11). It consists of a horizontal drum or rotor with a series of equal-sized pockets around the outer face. This drum is mounted at the lower end of a hopper between spring-loaded pressure plates.

The rate of feed is directly proportional to the number of revolutions per minute made by the drum. Rotors are made with shallow, medium deep pockets to suit the type of material being handled and the desired rate of feed. Outside scrapers or heavy balls riding on the inside of the rotors are used to remove the material which may cling to the underside of the rotors.

The rotary gate feeder is in many ways similar to the disk feeder described previously, as it will deliver an equal volume of material for each revolution. The uniformity of delivery by weight, however, depends upon the characteristics of the material being fed. Light compressible material will weigh more per cubic foot, when it is compacted by the weight of material in a full hopper. Granular material that is not uniformly graded may become classified in handling so that part of the time the machine will feed all fine or all coarse material, and part of the time a composite mixture. Aside from these variations which may be as much as 10 to 15 percent by weight, the usual specification calls for an error not to exceed ±5 percent by volume.

SOLUTION FEED EQUIPMENT

A number of different types of solution feeder are available for use in water treatment plants.

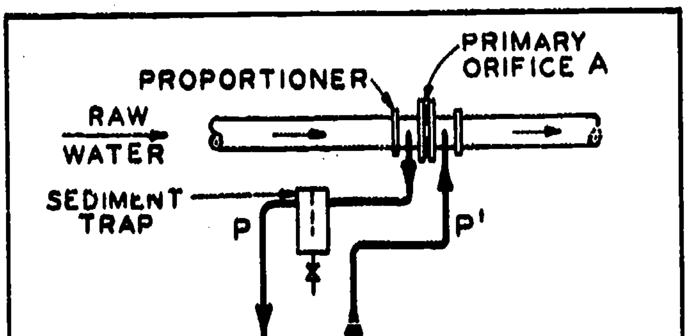

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Figure 8-12.—Pot-type solution feeder.

Among types that you may find commonly used are the pot-type and the decanter or swing pipe feeder.

Pot Type

The principle of operation of the pot-type solution feeder (see fig. 8-12) limits it to chemicals that can be obtained in lump, briquet, or ball form, and which are slow to dissolve when in continuous contact with water. As an example, when alum is used, it must be either potash or ammonium alum in lump form; and when alkali is used, it must be sal soda in similar form. Soda ash, filter alum, and similar chemicals should NOT be used in this type of feeder because they dissolve too fast.

The installation has an orifice plate in the raw waterline to be treated. An inlet line equipped with a sediment trap and a needle valve runs from the high or upstream side of the orifice to the underside of the dissolving pot. An outlet

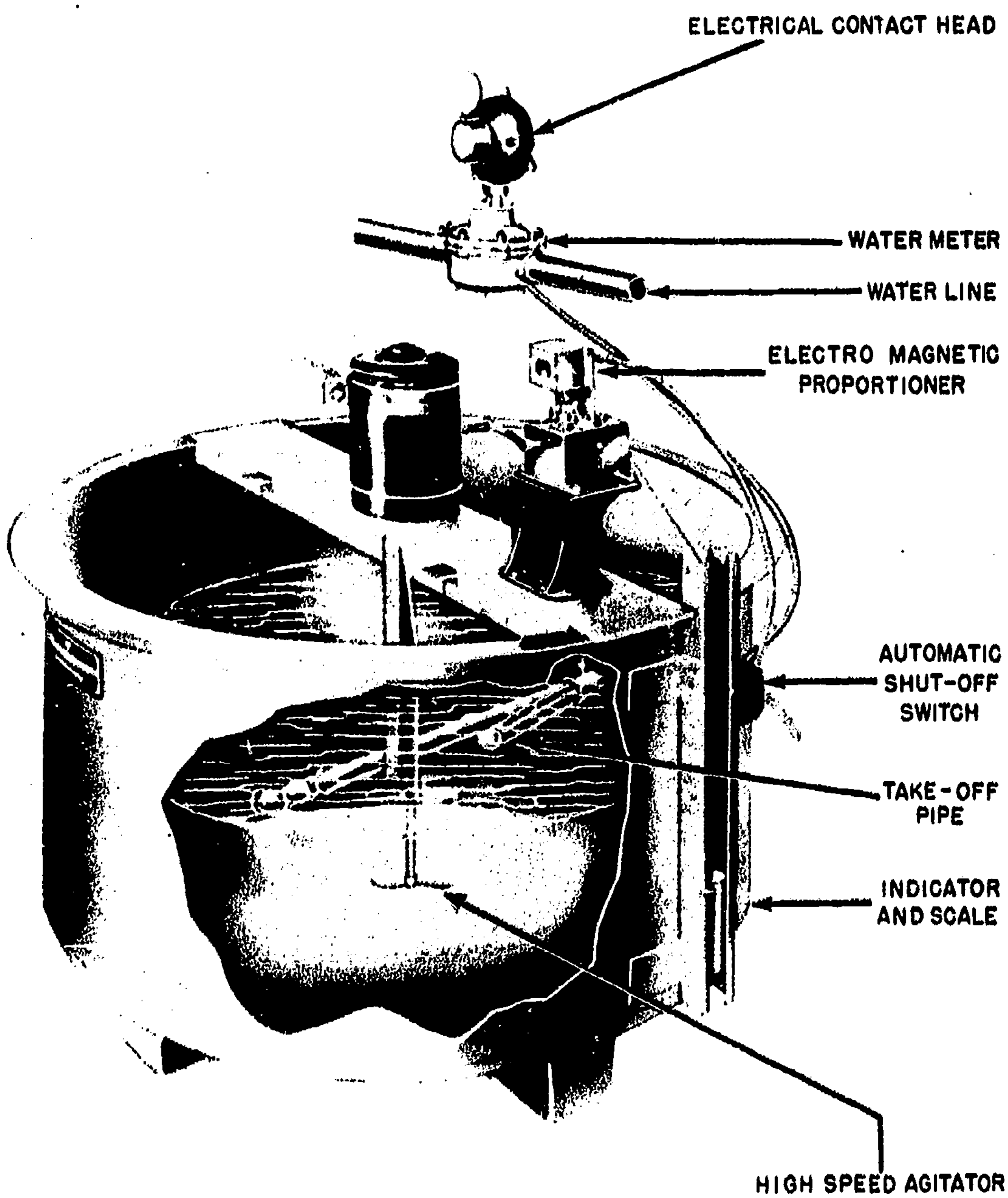

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Figure 8-13. —Decanter or swing pipe solution feeder.

line runs from the top of the pot to the low or downstream side of the orifice. Shutoff valves are provided in both lines to permit recharging the pot.

The pressure differential across the orifice plate in the main line causes a small stream of water to flow from the high pressure side of the orifice through the chemical pot to the low pressure side. This flow should force an equivalent stream of saturated chemical solution from the pot into the line. In theory, since the same differential pressure acts across the regulating valve as across the orifice, the discharge through the regulating valve at all settings will be a definite fraction of the flow through the orifice and will remain so in spite of variations in flow.

Pot feeders are made for charges of from a pound of chemical, or less, up to several hundred pounds. They are low in initial cost, but have the following limitations, especially where continuous service is required:

1. They are suited mainly to chemicals of limited solubility so that a saturated solution will be maintained for reasonable periods.

2. Where the solubility is low and the demand is high, a large throughput leads to excessive size, which is costly for positive pressure systems over 50 to 100 psi.

3. There is no assurance that the solution being fed is of constant, uniform concentration. The chemical bed may channel, temperature changes may affect solubility, and at high rates there may not be sufficient time for an equilibrium to be established.

4. The feeding of saturated solutions is always difficult in practice, however reasonable it sounds in theory. For example, crystallization frequently takes place in the regulating valve and outlet line so that an accurate calibration cannot be maintained.

To overcome these difficulties, the basic pot feeder has been modified to ensure feeding a solution of known concentration by using an immiscible (not capable of being mixed) liquid as a fluid piston or a bag as a separating membrane between the solution and the incoming water which displaces it.

Decanter or Swing Pipe Feeder

The decanter or swing pipe feeder (see fig. 8-13) uses a tank in which a chemical solution of suitable strength is prepared. Within the tank a drawoff head on a swing pipe is lowered by a feed control unit. The feed control unit is driven by a fractional horsepower motor which, acting through reducing gears and a pawl and ratchet wheel drive, slowly rotates a cable drum. This unwinds the cable, lowering the drawoff head in the chemical tank, thereby feeding the chemicals from the solution surface at a constant pressure and amount. The chemical may be picked up by a chemical pump supplying it to the water to be treated, or it may be discharged by gravity to the point of application.

SCALE CONTROL

Scale refers to the white or light colored deposit formed on the inside of pipes and other surfaces in contact with water as a result of the crystallizing out of the hardness found in natural and lime-softened water supplies (see fig. 8-14). Scale consists most commonly of calcium sulfate (gypsum) and may be mixed with corrosion products (rust), sand, or other sediment present in the water. The tendency of a given water to form a scale may be calculated from its chemical analysis and the temperature or, for calcium carbonate scale, may be found by measuring the hardness before and after passage through a container of finely divided marble. Scale formation is undesirable because it has the following bad effects:

1. Clogs pipes, thus reducing carrying capacity.

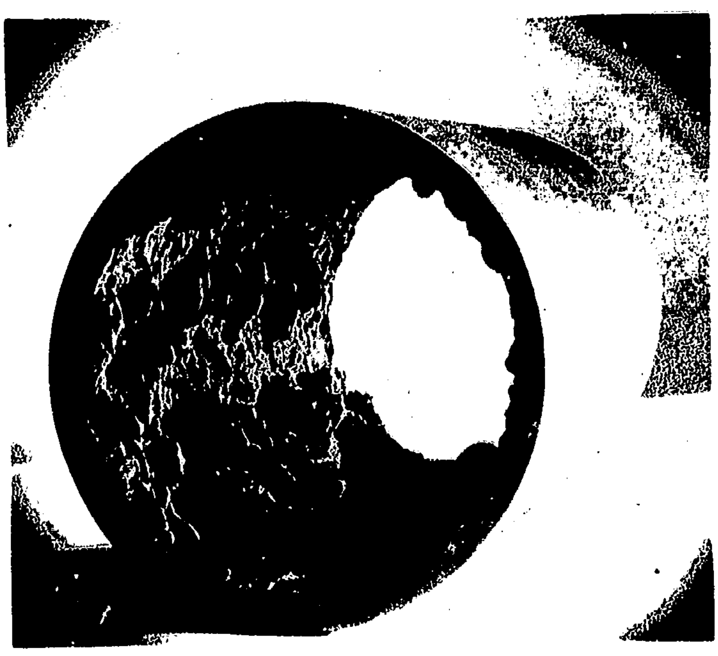

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Figure 8-14.—Water line containing heavy scale deposit.

2. Hinders operations by interfering with the functioning of valves and controls.
3. Reduces operating efficiency of heating and cooling systems.
4. Increases cost and reduces effectiveness of laundering and other soap-using processes.

Scale formation can be controlled by threshold treatment or by softening of the water to remove scale-forming elements. Softening may be carried out by ion exchange or lime-soda treatment.

THRESHOLD TREATMENT

Carbonate scales can be prevented by the addition to water of very low concentrations of polyphosphates (glassy phosphates; hexametaphosphate). There is no true chemical reaction. The added polyphosphate prevents any tiny crystals of scale which may form from growing, thereby preventing a buildup of scale (see fig. 8-15). The water is stabilized without actual removal of the scale-forming constituents. The maximum concentration of calcium bicarbonate that can be stabilized by threshold treatment varies with the temperature and the alkalinity of the water. For normal temperatures in the range of 50° to 70° F, a quite hard water can be stabilized with 2 ppm of glassy phosphates. When polyphosphates are used for scale control, dosage must be carefully controlled. Overdosing may result in a phosphate scale formation.

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Figure 8-15.—Effect of threshold treatment for scale prevention. (Left) Without treatment. (Right) With treatment.

SOFTENING BY ION-EXCHANGE (ZEOLITE)

Ion-exchange water softening is a chemical operation in which calcium and magnesium, the hardness-forming materials in water, are exchanged for other materials which will not form a scale. This action is accomplished by passing the water through a bed of a solid ion-exchange medium, such as zeolite; which will capture and hold the calcium and magnesium in the water, releasing to the water in exchange an equivalent amount of sodium. See figure 8-16 for an illustration of an ion-exchange softener. These ion-exchange materials used in the process are insoluable, granular, solid materials that possess this unique property of exchange. They may be natural mineral zeolites, such as glauconite (greensand); precipitated synthetic substances of chemical composition similar to natural zeolites, organic (carbonaceous) zeolites; or synthetic ion-exchange resins. Currently, the resins are used most commonly.

Operation of Ion-Exchange Units

The manufacturer's instructions should be consulted for the details of operation of specific ion-exchange units. There are four steps in the ion-exchange softening process; they are backwash, regeneration, rinse, and service.

BACKWASH.—During the softening period, water flowing downward through the zeolite bed leaves suspended matter on the surface of the bed. As this accumulation grows, the pressure drop across the bed increases and the bed becomes more compact. Therefore, when the zeolite bed becomes exhausted, it is necessary not only to regenerate it, but also to backwash it to remove the surface deposit and to ensure efficient regeneration and later operation. Backwashing consists of flowing water upward through the bed at a rate which causes the bed to expand a specified minimum amount. This permits dirt to be separated from between zeolite grains and floated off at the top to the sewer. It also cleans and loosens the bed so that in the succeeding regeneration step the salt solution can properly contact all the zeolite.

REGENERATION.—In the course of softening water, the sodium content of the ion-exchange bed is depleted and requires regeneration by passage through it of a common salt solution in order to restore its capacity to remove hardness from water. The sodium of the salt displaces the calcium and magnesium taken up by

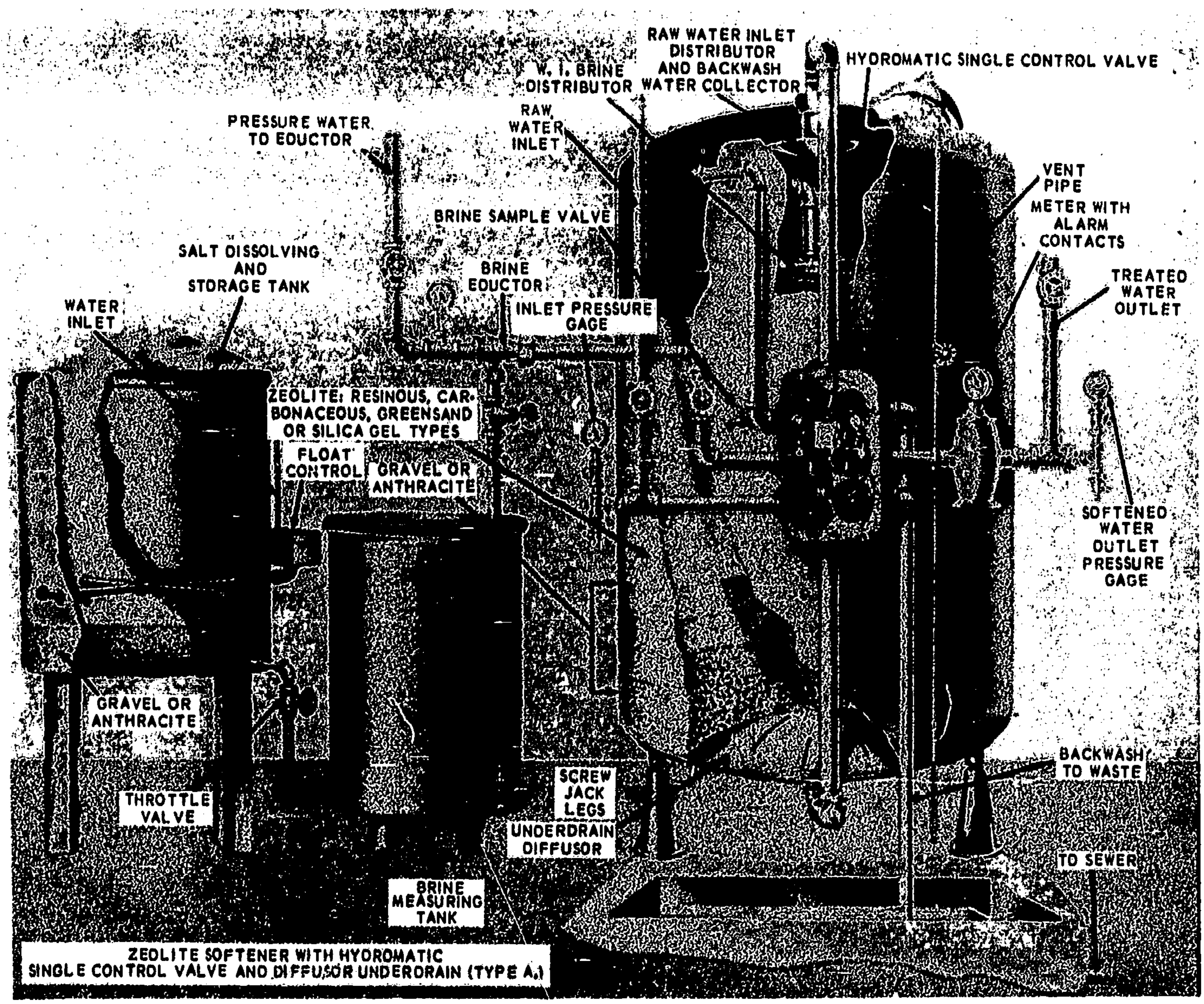

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Figure 8-16.—Ion-exchange unit for water softening.

the bed during the softening step and restores the ion-exchange material to its original condition. The salt solution is fed into the softener above the resin bed and flows downward. The efficiency of this operation is determined by use of the proper amount and strength of salt solution, distribution and rate of flow, and time of contact with the bed. The salt solution should be added slowly. For greensand, allow about 5 minutes. For other materials follow the manufacturer's instructions (usually 15 to 20 minutes).

RINSE.—After regeneration, the ion-exchange bed must be rinsed to flush out the excess salt solution. To accomplish this, water is passed through the bed until all traces of salt have been thoroughly washed out. Rinse at rates recommended in the manufacturer's instructions. Ordinarily the rate is about 2 gpm per square foot of bed surface area with about a 20-minute rinse period. Synthetic resins require a longer rinse.

SERVICE.—After the bed has been regenerated and rinsed, the softening process is resumed by passing raw water downward through the bed at the manufacturer's recommended flow rate, and into the effluent mains. This flow is continued until the bed is again exhausted and regeneration is again required.

Supplementary Treatment

An ion-exchange softener produces water of zero hardness. Since this water will not form a protective coating on distribution piping, oxygen in the water will cause rusting of exposed iron. It is, therefore, desirable to mix the softened water with unsoftened water to obtain the desired degree of hardness. If the unsoftened water contains more than 0.3 ppm hardness, the unsoftened water should be aerated and filtered before it is mixed with the softened water. The pH of ion-exchange softened water may be adjusted to make the water less corrosive by addition of a caustic-silicate solution.

SOFTENING BY LIME-SODA

Water may also be softened by adding lime, or lime and soda ash, to precipitate the hardness-causing compounds. After precipitation, the insoluble compounds are removed by sedimentation and filtration. Lime-soda softening plants are constructed essentially the same as water filtration plants. Lime (and soda ash) are added to the raw water, and the softening reaction occurs during mixing and flocculation. The precipitated calcium and magnesium compounds are removed during sedimentation. An additional step, called recarbonation, is frequently provided just prior to filtration in order to stabilize the water so as to prevent further precipitation in the filters and distribution mains. If raw water has a high turbidity, the turbidity is partially removed by plain sedimentation prior to the softening process.

IRON AND MANGANESE REMOVAL OR CONTROL

Iron is present in many ground waters, whereas manganese is present only occasionally, and then usually along with iron. The presence in a water supply of more than 0.3 ppm of iron, or more than 0.5 ppm of manganese, is considered objectionable. These compounds stain everything with which they come into contact. This is especially true of plumbing fixtures and clothes that are rinsed in water. Iron and manganese affect certain foods, such as causing tea to turn black and darkening vegetables cooked by boiling. Iron also favors the growth of various bacteria generally known as "crenothrix." These crenothrix growths are stringy and gelatinous, and may become so voluminous as to interfere with the flow of water through the pipes. Manganese stains, especially on clothes, are even more objectionable than iron rust because they are darker. Deposits of manganese oxide are almost black. Iron and manganese can be removed from water, or their undesirable effects eliminated, by the methods described in the following subsections.

THRESHOLD TREATMENT

If the amount of ferrous iron does not exceed 2 to 3 ppm, color and staining can be prevented by the threshold treatment described in the previous section on scale control. In this treatment, the addition of about 2 ppm of polyphosphate is required to sequester 1 ppm of iron. To be effective, it is important to add the polyphosphate to the water before the latter comes into contact with air, or is treated with chlorine. Polyphosphates will hold manganese in solution provided that the manganese does not exceed approximately 1 ppm. A weight ratio of 2 ppm polyphosphate to 1 ppm manganese is required. As with iron, the polyphosphate must be added before contacting the water with air or chlorine.

CHEMICAL PRECIPITATION OF IRON

Iron dissolved in water as iron bicarbonate is removed by oxidizing it to insoluble ferric hydrate, a gelatinous rust-colored material. Methods of removal are influenced by the presence of organic matter, carbon dioxide, and carbonates. Organically combined iron can best be removed by coagulation and filtration.

AERATION

In waters high in carbon dioxide and containing no dissolved oxygen, iron exists as ferrous bicarbonate. When the water is aerated, carbon dioxide is released, iron changes to ferrous hydroxide and, on contact with oxygen, is oxidized to ferric hydrate. Ferric hydrate is not soluble. It looks like ordinary rust and is readily removable by sedimentation and filtration. Spray, wood, and coke-tray type aerators are efficient and require little attention in operation. See figure 8-17 for an illustration of an aerator. Aeration to oxygen saturation is not recommended with low alkalinity waters because it increases corrosiveness. With such water, if the pH is not too low, limited amounts of oxygen can be introduced by a "snifter" valve in the waterline just before a pressure filter which then removes the ferric hydrate floc.

CONTACT OXIDATION

The method of contact oxidation is used to remove iron that is present in small amounts (less than 0.1 ppm) or remains in solution after other processes have removed the bulk of it. A

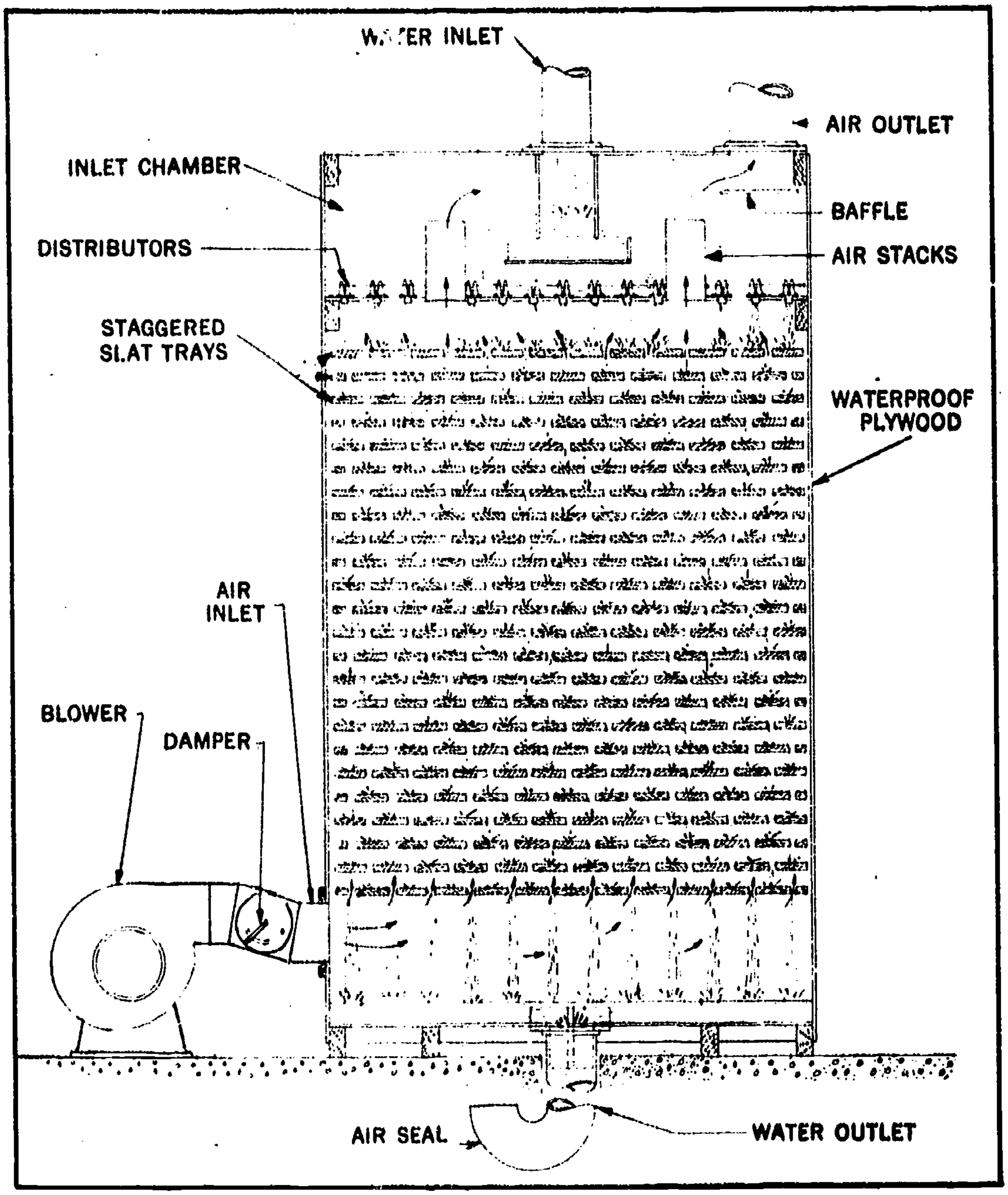

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Figure 8-17.--Aerator.

greensand zeolite treated with manganous sulfate and potassium permanganate (called manganese zeolite) oxidizes the iron from soluble ferrous state to the insoluble ferric state and deposits the iron oxides formed on the zeolite grains. Regeneration is carried out with potassium permanganate solution which restores the oxidizing capacity of the bed.

SAND FILTERS

When iron is incompletely precipitated by aeration and sedimentation, sand filters act as contact beds and remove most of the remaining iron. The oxidizing action is confined to the upper portion of the bed and results in coating the sand with iron oxide, which has been found to be more active than clean sand for iron removal.

CHEMICAL PRECIPITATION—MANGANESE

Manganese, when present, is almost invariably associated with iron. Due to its chemical similarity to iron, it is removed by the same process.

However, manganese is not oxidized as readily. This is shown, for instance, by the presence of black manganese stains below the iron stains in sand filters. The following differences in treatment should be noted:

1. Simple aeration and filtration are seldom adequate for manganese removal. It is necessary to increase the pH of the water to about 9.4 before effective precipitation of manganese can be obtained by this means.
2. Oxidation of the manganese with chlorine, followed by coagulation, sedimentation, and filtration usually gives satisfactory results.
3. Filter sand with a manganese dioxide coating aids in removing manganese.
4. Contact aerators are quite effective in removing manganese.

ION-EXCHANGE FOR IRON AND MANGANESE REMOVAL

In the process of softening, a sodium zeolite will also remove any dissolved iron and manganese. In some instances, the softening process becomes incidental to the principal objective of removing iron and manganese. All of the iron and manganese must be in solution in the ferrous or manganous state before passing through a zeolite bed of this type, otherwise a precipitate will form that will clog the bed. Therefore, air lift pumps, pneumatic tanks, or other aerating devices cannot be used ahead of the zeolite beds in this process. Operating procedures are the same as described earlier in the discussion on softening by ion-exchange (zeolite).

CORROSION CONTROL

The control of corrosion is important for maintaining the delivery capacity of the mains, prolonging the life of equipment, and protecting the quality of water delivered. Whenever corrosion is minimized, there is an appreciable reduction in maintenance and operation costs. Corrosion, especially when it attacks installation utility systems, can seriously interfere with accomplishment of the activity mission by causing plant shutdown for repairs and by wasting critical materials. Corrosion causes leaks in mains and domestic piping, resulting in the waste of water. Products of corrosion cause clogged pipelines and equipment, and reduction in pipeline flow capacity. Corrosion also causes water to become turbid and imparts color which will stain fixtures and clothing in laundering. Corrosion control is, however, a complex engineering problem because of the many combinations of causes, influencing factors, and effects that are possible in any situation. Because the major controlling factor is one of design, the discussion in this chapter is limited to a brief description of corrosion and some of the methods used for control.

THEORY OF CORROSION

Corrosion is commonly considered to be an electrochemical reaction in which metal deteriorates or is destroyed in contact with its environment or surroundings, such as air, water, or soil. Corrosion is essentially the same in all metals. Such refined metals as steel are relatively unstable and tend to change back to the stable compounds, usually oxides of their natural ores.

The term ELECTROCHEMICAL REACTION means that chemical changes and an exchange of electrical energy take place at the same time. Thus, whenever corrosion occurs, there is a flow of electric current from the corroding portion of metal into the electrolyte or conductor of electricity, such as water or soil, and back into the same metal at another point or into another metal which forms an electrical contact with the corroding metal. The point at which current flows from the metal into the electrolyte is called the ANODE, and the point to which the current flows from the electrolyte back into a metal is called the CATHODE.

The electric current flowing from the metal carries charged particles, called IONS, of the metal with it. As the metallic ions are dissolved in the electrolyte, they are exchanged for hydrogen ions, which flow to the cathode and tend to deposit a hydrogen film on the cathode. The metallic ions carried from the parent metal are usually changed to oxides by dissolved air in the electrolyte, and are deposited as corrosion products, most often near or on the anode. In the case of steel, these oxides form the familiar rust.

GENERAL METHODS OF CORROSION CONTROL

In a given situation corrosion may have one cause or many; hence, control measures must be planned to meet the specific conditions. Since it would be impossible to give specific measures covering all local problems, a number of overall control measures will be discussed in sufficient detail to guide personnel in establishing corrosion control measures and solving specific problems.

The most important weapon against corrosion is, of course, proper design. As a UT, you will not be primarily concerned with design. You may be interested to know, however, that design entails the selection of proper materials, the allowance of extra thickness of metals where it is known corrosion may occur, the proper protection of metals by protective coatings and linings, the installation of cathodic protection systems, and the provision of adequate water treatment devices.

Cathodic Protection

As previously indicated, whenever current leaves a metal surface located in an electrolyte, electrically charged particles of the metal go into solution, causing corrosion. If the flow of this current can be stopped or reversed, theoretically the metal will not corrode. In cathodic protection, the current flow is retarded by passing an auxiliary current through the electrolyte to the metal.

Cathodic protection is defined as the application of sufficient direct current to a metal object, counter to the normal corrosion current, to prevent current from leaving the anodic areas of the structure. The entire metal object then becomes negative or cathodic to its surroundings. For each environment, a certain minimum current must be applied to minimize corrosion. The source of current is immaterial, as long as the amount of current is adequate.

Steel elevated water storage tanks are often protected from corrosion by means of cathodic protection. Typical equipment consists of a rectifier to produce a direct current from the alternating supply, control rheostats, an ammeter, and carefully sized and spaced electrodes suspended from the tank roof into the water.

The electrodes, made of platinum or aluminum, are connected to the positive wire of a d.c. circuit. The negative wire is connected to the tank bottom, completing the circuit for current flow from the electrodes to the tank surface. The induced electrical current flows continuously from the electrode to the tank. This current must be equal in all parts of the tank. Current density of about 5.0 milliamperes per square foot is necessary for bare metal; less is required if the tank is partially protected by paint.

For even distribution of current density, it is essential to place the electrodes at certain predetermined locations, otherwise full protection for the entire submerged surface will not be secured. In wide diameter water tanks, it is necessary to locate a group or circle of electrodes near the tank sidewalls, with another group around the center area to protect the tank floor. For protection of the riser, a long electrode is usually suspended within a few feet of ground level.

The current requirement to provide complete cathodic protection varies with a number of factors, the most important of which is the resistance of water and the number, diameter and spacing of the electrodes. For water with high resistance (low dissolved solids content), higher current densities are required than for water with low resistance.

In addition to steel elevated water storage tanks, other water supply equipment can also be protected from corrosion by application of the principle of cathodic protection. This includes steel sedimentation basins, flocculators, and the outside surfaces of piping systems.

Protective Coatings and Linings

Protective coatings and linings serve as barriers between the metal to be protected and the corrosive environment. In many cases it may be more economical to use a protective coating than to use a more resistant material. Depending on the circumstances, protection may be needed either internally or externally. Protective coatings and linings may be either nonmetallic or metallic. Nonmetallic protection includes paint and enamel coatings, cement masonry, plastic linings, rubber sheeting, and glass and ceramic coatings. Metallic coatings include galvanizing and cladding or plating with more corrosion resistant metals.

Corrosion Inhibitors

Water is frequently treated to eliminate the causes or to reduce the intensity of corrosion. Chemical treatment for corrosion control generally consists of the addition of chemicals to adjust the pH of the water and to effect the deposit of a solid or gelatinous film on the metal surface. This film, when evenly formed, effectively isolates the metal surfaces and prevents direct contact between water and metal.

CALCIUM CARBONATE.—Calcium carbonate will deposit a film on cathodic areas because of the greater alkalinity of these areas. The film excludes oxygen from those areas, thus reducing cathodic reaction. Raising the pH of the water slightly above its calcium carbonate saturation value will sometimes cause a thin calcium carbonate film to be continuously deposited on the metal. Treatment varies with the composition of the water. Hard alkaline waters may require the addition of only slight quantities of soda ash. Soft waters of low alkalinity may need both lime and soda ash.

PHOSPHATES.—Glassy phosphates such as Calgon, Nalco 918, and similar compounds have wide application in treatment for minimizing the effects of corrosion in water supply systems. Corrosion inhibition is caused by the absorption of the phosphate, or one of its complexes, on the material surface, forming a protective film. The rate of supplying the phosphate to the metal surface is the important factor rather than its concentration in the water.

For initial installations, it is desirable to have a high dosage (10 ppm) to form a film as quickly as possible. A modified polyphosphate containing zinc is sometimes used initially for this purpose. As soon as the protective film has formed, the dosage can be reduced from 10 ppm to 2 to 4 ppm, depending on what is required to maintain a film on the metal.

Phosphates are useful in a pH range of 5 to about 8, with best results obtained in pH ranges from 6.5 to 7. When beginning polyphosphate treatment in corroded pipe systems, difficulty is often experienced with the sloughing off of existing corrosion products. Therefore, care is required to avoid complaints.

Chemical feed is usually by solution feeders similar to hypochlorinators. Since polyphosphate solutions support bacterial growth, use a small amount of hypochlorite (2 to 3 ppm residual chlorine) in the feed solution to avoid contamination.

SODIUM SILICATE.—The addition of sufficient quantities of soluble silicates to water will produce a precipitation of a thin, gelatinous metal silicate film on the metal. To maintain this film, sodium silicate must be fed continuously at a rate of about 30 ppm (8 ppm silica addition). Silicates are best adapted to the treatment of very soft waters.

TASTES, ODORS AND ODOR CONTROL

Water must be free from taste and odor as well as be safe. If the water supply has an unpleasant taste or odor, consumers will probably use any other available supply, whether or not it is safe. Taste and odor control involves treatment to prevent taste or odor formation or corrective treatment after formation. The principal causes of unpleasant tastes and odors in water are as follows:

1. Pollution by industrial wastes, such as those from canneries, chemical manufacturing plants, and by-product coke plants.
2. Excessive algae growths and slime deposits.
3. Decomposition of organic matter.
4. Dissolved gases, such as hydrogen sulfide (rotten egg odor).

Depending upon the causes, tastes and odors can be reduced by aeration or by treatment with activated carbon, copper sulfate, chlorine, or chlorine dioxide. Depending upon the type of problem, taste and odor control chemicals may be added to the raw water in the reservoir or in the treatment plant during rapid mix or flocculation after sedimentation or prior to filtration.

AERATION

Aeration is mainly effective for removal of dissolved gases; and, for most other odors, must be used in conjunction with other treatments. It is of little value for removal of algae or industrial waste odors. Aeration for removal of sulfide consists of exposing as much water surface as possible to the air. During aeration, gases dissolved in the water supply are released to the atmosphere.

Some types of aerators consist of overflowing trays or trays containing slats or coke over which the water is sprayed. Other methods include spraying water up over a shallow receiving basin and forcing air into the basin with diffusers or mechanical pump-type aerators.

The operation of most aerators is practically automatic. The operator's duties consist essentially of making sure that pipes, spray heads, and surfaces are not clogged, and that air has free access to the water. If water is not to be filtered after aeration, aerators must be equipped with fine screening to keep out insects and other foreign matter. Daily, observe compressor or blower discharge pressure at normal rate of air flow. An increase usually indicates diffuser clogging. Also, observe bubble pattern in aeration tanks.

ACTIVATED CARBON TREATMENT

Activated carbon is specially treated granular or powdered carbon which, because of its tremendously increased internal surface area, will absorb larger quantities of dissolved gases, liquids, and finely divided solids than ordinary carbon. It is highly effective in taste and odor control, provided that the type of activated carbon used meets required standards, the dosage is correct, the carbon is mixed intimately with the water for an adequate time.

Acceptable commercial preparations of activated carbon are available under a number of trade names such as Aqua Nuchar, Cliffchar, Hydrodarco, and Norit. Any type may be used if it meets the following minimum standards:

1. It may not contain soluble minerals injurious to health.
2. The weight should be 10 to 11 pounds per cubic foot.
3. The moisture content should not be over 8.0 percent.
4. It should contain at least 90 percent pure carbon.
5. It should be powdered form, which wets down and goes into suspension readily, does not settle too rapidly, and does not float on the surface when applied.
6. At least 99 percent of the carbon in water suspension must pass a 100-mesh sieve, and at least 94 percent must pass a 200-mesh sieve.

Because of the wide range of odors in different waters, no general rule can be given for activated carbon dosage. The dose required at each plant must be determined by periodic laboratory tests.

The test is made by preparing a number of samples of raw water, adding standard amounts of treating chemicals and varying amounts of carbon in each sample, allowing plant contact time, filtering, and making odor tests. Numerical comparison can be made with the threshold odor test. Generally, the amount of carbon required in the plant is less than that indicated by the laboratory test.

A carbon dose of 3 ppm removes most tastes and odors from water. However, if the tastes and odors are caused by pollution from industrial wastes, the dose may have to be increased to 8 to 10 ppm, or even 20 ppm at times. When odors develop suddenly, feed an excess dose until they are under control.

Normally, activated carbon is fed into water by dry feeders somewhat similar to those used for coagulants. (Information on dry feeders used for coagulants was presented earlier in this chapter). Because activated carbon is so finely powdered, it must be handled more carefully than coagulants to guard against spreading carbon dust and causing fires or explosions. In addition, motors, lighting fixtures, and switches must be explosion-proof. If dry carbon were dry-fed onto the water, it would float on the surface for a long time. Therefore, to ensure better mixing, the carbon is first wetted thoroughly, usually by agitating it with the feed water in a small box or tank. The agitating agent may be a paddle wheel, a strong spray, or a swirling action obtained by introducing the feed water at a tangent to the side of the tank. Most carbon dry feeders have a mixing chamber or hopper in which the carbon is wetted by the swirling action of the water.

Activated carbon may be applied to the water at one or more of the following points, depending upon the results desired:

RAW WATER. Application of the chemical should be as early as possible after entering the plant, but this point of application is not recommended for extremely turbid waters.

MIXING BASINS. When added before sedimentation, activated carbon not only removes foreign matter from the water, but the carbon which settles in the sedimentation basin continues to absorb products of sludge decomposition, thus preventing formation of secondary tastes and odors. It also permits the use of high dosages without adversely affecting the length of filter runs.

TREATMENT PLANTS. Applying carbon just before filtration is recommended because it is not then removed during coagulation and flocculation, and its effect continues during the filtration process. The carbon that accumulates in the filter helps remove tastes and odors. When a filter is returned to service after backwashing, it is good practice to add a small batch of carbon to the filter influent.

SPLIT FEED. When part of the dosage is applied in the mixing basin and the balance just ahead of the filters, it is referred to as split feed. Proportions of the dosage at these two points depend on the water being treated. This method combines the advantages of both feed methods and often gives better results than a larger total carbon dosage applied at a single point.

FILTERS. Granular activated carbon can be used as the filter medium in gravity or pressure filters. Operation is identical to that of sand filters but backwash rates are lower to prevent loss of carbon.

ALGAE CONTROL

The presence of algae does not make water unsafe. However, uncontrolled algae growth frequently causes unpleasant tastes and odors and may clog pipes and filter beds. Taste and odor problems are caused by a wide variety of algae, the type and intensity of the problem varying with the particular algae concerned. Algae growths occur mainly in large open reservoirs, in sluggish streams, and in surface supplies. Sunlight is necessary for their existence.

Algae growth can be controlled by the use of algicidal chemicals and the alteration of environmental conditions such as the reduction of light intensity, the latter being applicable usually only in small storage basins and tanks. Control of algae with copper sulfate, activated carbon, or chlorine are standard chemical methods.

Copper Sulfate

In soft waters, 1 ppm of copper sulfate (8.34 pounds per million gallons of water) destroys most algae. Larger dosages are needed in hard water because some of the copper is precipitated by the alkalinity in waters. Effective hard water dosage may be from 1 to 4.5 ppm, depending on the alkalinity of the water.

Weight, in respect to the volume of water, is parts per million (ppm). This unit is an abbreviation of the expression: "Parts by weight of substance per one million parts by weight of water." The word "part" refers to similar units and may be used to indicate any unit of measure. For example, 1 lb of copper sulfate per million pounds of water or 1 grain of copper sulfate per million grains of water are both expressed as 1 ppm. However, water is not measured by weight, so the weight of a gallon of water is used to convert pounds per million gallons to parts per million. A gallon of water weighs 8.34 lb, so one million gallons weigh approximately 8,340,000 lb. Therefore, 8.34 lb per million gallons equals 1 ppm.

$$\text{Lb of copper sulfate} = \frac{\text{gals of } H_2O \times 8.34 \times \text{ppm}}{1{,}000{,}000}$$

For example, 200,000 gallons of water to be treated, with 2 ppm copper sulfate

$$= \frac{200{,}00 \times 8.34 \times 2}{1{,}000{,}000}$$

$$= \frac{3{,}336{,}000}{1{,}000{,}000}$$ 3.336 or 3 1/3 lb of copper sulfate needed.

Because copper sulfate kills fish, its use is limited. Concentrations that kill common varities of fish and limiting safe dosages are listed here in ppm of copper sulfate per million parts of soft water. Fatal concentrations are considerably higher in hard waters.

	Toxic Concentrations ppm	Limiting Safe Dosage ppm
Trout	1.2	0.14
Catfish	2.5	0.40
Suckers	2.5	0.33
Carp	2.5	0.33
Pickerel	3.5	0.40
Black Bass	17.0	2.00
Perch	6.0	0.67

Before the chemical is applied, the volume of water in the reservoir to be treated is computed carefully to avoid underdosing or overdosing. Usually only that part of the reservoir showing algae growths should be treated. Algae growths are generally found in shallow areas and around the shoreline. In computing water volume, the maximum depth is taken at 5 feet. Algae seldom grow below a 5-foot depth, because this is the maximum effective penetration of sunlight. Copper sulfate treatment is most effective if started early in the season before heavy algae concentrations have formed. The treatment is repeated whenever algae growths reappear.

SOLUTION FEED. If copper sulfate can be applied by solution feeders to the water entering the reservoir, continuous application of lower concentrations can be used instead of intermittent treatment. This usually results in the most efficient control of algae growths.

BAG FEED. The simplest, though not the best, method of applying copper sulfate is to tie a bag of copper sulfate crystals to a boat and cover the reservoir in a definite zigzag pattern.

SPRAY FEED. In reservoirs needing frequent treatment, the best method is to spray the copper sulfate solution or crystals on the water surface from a spray unit mounted in a boat. Apply the copper sulfate evenly to avoid overdosing shallow areas.

Activated Carbon

Because algae grow only in sunlight, they can be eliminated by preventing light from entering the water. This is the principle behind the the activated carbon method of algae control. Usually carbon dosages of 6 to 20 pounds per million parts of water place enough carbon in suspension to absorb all light. The carbon also removes tastes and odors in the water. This method is used only for relatively small basins or tanks. The use of activated carbon in large reservoirs is impractical.

Chlorine

Chlorine dosage of 0.3 to 1 ppm at the plant destroys most algae, but may intensify odors. The break-point method of chlorination requires higher dosages, but eliminates tastes and odors and kills algae as well. With this method, chlorination dosages vary from 0.8 to 10 ppm, or higher, in exceptional cases. Chloramines have in some instances also been found to be an effective method of controlling algae growth.

COLOR REMOVAL

Color in natural waters is caused mainly by vegetable matter or by excessive amounts of iron and manganese. Minerals contained in industrial wastes may also cause color. The coloration is usually caused by colloidal matter and may be removed in the same manner as other colloids, by chemical precipitation, coagulation, or adsorption, followed by filtration. No one method will remove all colors, and no single rule will apply to all waters. Color removal requires trial of the following methods to determine which is most efficient and economical in a particular situation.

Coagulation with alum, followed by lime or soda ash if necessary, and filtration is the most common method. The alum must be added first and given some reaction time at a pH of 5.5 to 6 before adding the alkali. If the alkali is added first, it will "set" the colors and prevent removal.

The addition of chlorinated copper as a low pH with an alum dosage applied halfway through the coagulation basin has been very successful in some instances. Dosage has to be determined by trial.

Color removal by chlorination requires a dosage of 1 to 10 ppm, the correct amount being determined by trial. A detention or contact time of at least 15 minutes is necessary, and not less than 0.1 ppm free or combined residual should be maintained.

Some color is susceptible to removal by activated carbon. The colloidal matter is adsorbed by the carbon and is then removed by sedimentation and filtration. Tests of carbon applied to a particular water is the only method of determining the effect of carbon for color removal.

FLUORIDE ADJUSTMENT OF WATER

The Navy Department subscribes to the principle of minimizing dental cavities among children (16 years old and younger) at Navy shore activities, where children reside, by adjustment of the fluoride content of the station water supply to recommended levels. If your duties involve the fluoride adjustment of water, note that current instructions issued by joint instruction from the Bureau of Medicine and Surgery and the Naval Facilities Engineering Command (formerly Bureau of Yards and Docks) should be followed.

CHAPTER 9

CLARIFICATION OF WATER

This chapter provides information on various types of equipment and processes used in the clarification of water.

The term "clarification" refers to the removal from water of floating or suspended mud, clay, living or dead aquatic organisms or growths and other material to produce a relatively clear, clean liquid.

Plain sedimentation (settling) is seldom used alone for the clarification of water. Due to increasing pollution of water sources, the sedimentation process usually is not sufficient and it must be followed by filtration. Plain sedimentation is rapidly being replaced by mechanical and chemical treatment in order to reduce the size of units, to increase efficiency, and to improve treated water quality. Coagulation and sedimentation are usually followed by filtration.

The type and degree of treatment will depend upon the nature of the raw water, which will vary widely depending on its source. In general, the process entails coagulation (including flash mixing and floc conditioning), settling or sedimentation and filtration. See figure 9-1 for a schematic diagram of the clarification process.

A recent development, particularly useful for the removal of the bulk of heavy algae suspensions prior to the conventional clarification or filtration processes, is microstraining. In this process, the raw water passes through a rotating, fine mesh screen which is continuously backwashed by a spray arrangement.

COAGULANTS AND COAGULATION

Coagulation includes the addition of chemicals which form a gelatinous precipitate (floc) to entrap suspended matter and color, and the enlargement of the particles so that they settle rapidly. Most water sources, and especially surface streams, contain enough finely divided material in suspension to require coagulation for removal before filtration, even though the water may have been previously subjected to plain sedimentation. In addition, a certain form of algae and microorganisms act as a form of suspended matter and may be removed by coagulation, flocculation, and settling in the sedimentation basin.

Coagulation is accomplished through the addition of a chemical called a coagulant, which reacts with alkalinity in the water to produce a gelatinous precipitate or floc. The gradual growth of this floc by a slow mixing process is called flocculation. During the growth process, the floc increases in size, absorbs color, enmeshes bacteria particles causing turbidity, and with its increased weight settles to the bottom of a sedimentation basin provided for this purpose.

The equipment used to promote the growth of floc is called a flocculator, and the basin or chamber in which it is installed is called the flocculating basin. It is in the processes of coagulation, flocculation, and sedimentation that the greatest removal of suspended matter takes place.

The process of coagulation involves complex chemical and physical reactions beyond the scope of this manual. However, in basic terms, the addition of a coagulant to water produces two actions, one electrical and one chemical. The suspended particles of mud and clay carry minute negative electrical charges. The coagulant floc is a colloidal, hydrous oxide, with a small positive charge. The positive charges attract and neutralize the negative charges, thus causing an agglomeration or joining together of the suspended particles and the floc. As this combined particle develops and increases in size, it becomes dense enough to settle out of the water.

CHEMICALS USED AS COAGULANTS

A number of different types of chemicals are used as coagulants. Some of the more widely used coagulants are discussed briefly below.

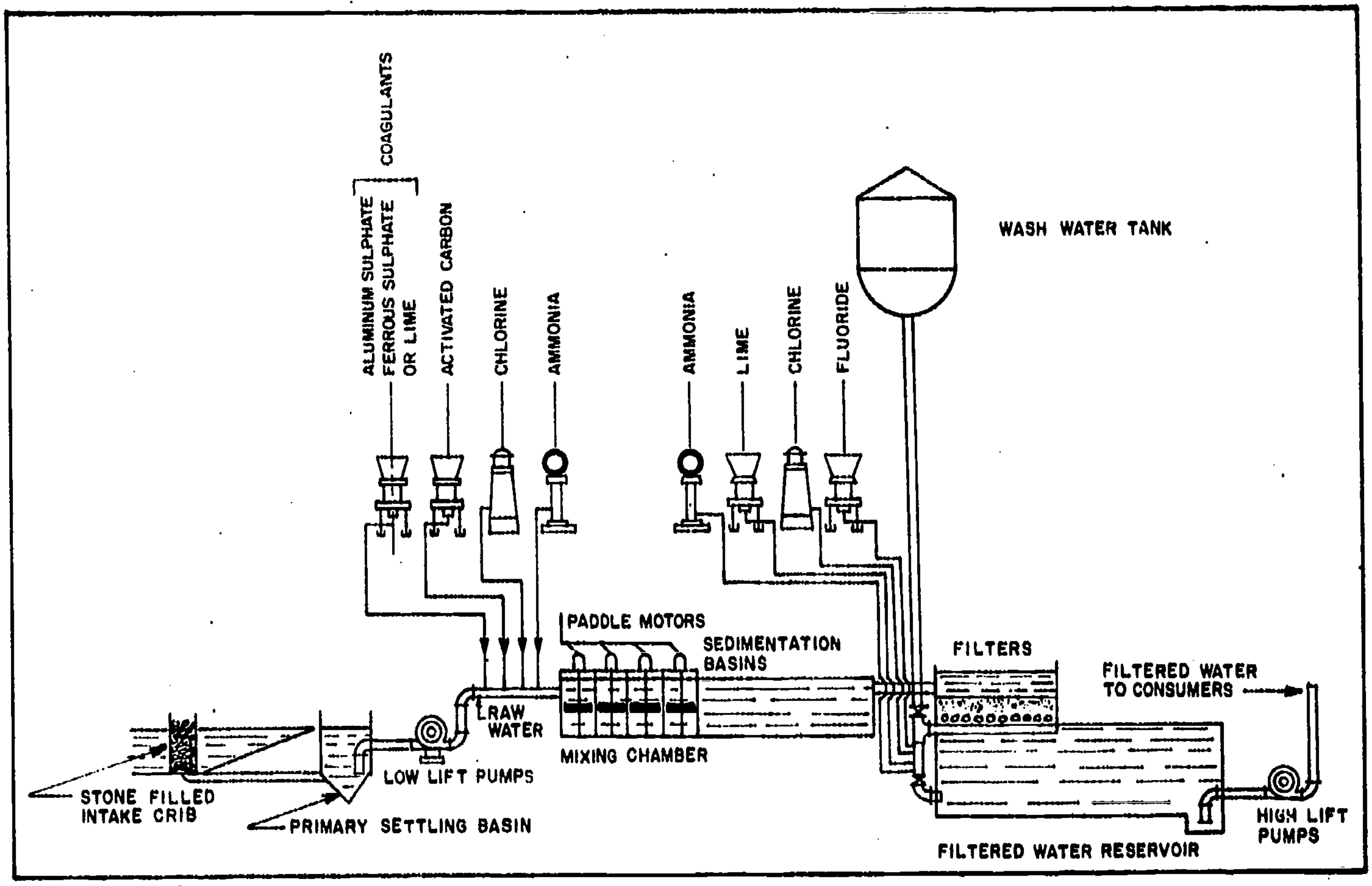

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Figure 9-1.—Schematic diagram of clarification process.

Aluminum Sulfate

Aluminum sulfate (filter alum) may be added to a water containing natural alkalinity in the form of calcium or magnesium bicarbonate.

When water does not contain sufficient natural alkalinity to react with alum, an alkali such as calcium hydroxide (hydrated lime) is added. Sodium carbonate (soda ash) may also be used with alum to supply the necessary alkalinity.

It is advantageous to use alum alone when possible, since it greatly simplifies control of the treatment process. It does not intensify color that may be present in the water and may actually reduce the color already present to some extent. Ordinarily, the resulting increase in hardness and corrosiveness is of little consequence. The minimum dose should never be less than 5 ppm even with relatively clear water in that smaller doses will not produce the concentration of aluminum hydroxide necessary for floc formation. The usual pH range for use of alum is 5.5 to 6.8.

Ferric Salts

Liquid, crystalline, and anhydrous (without water) ferric chloride are available as coagulants. Ferric chloride is corrosive in the liquid state, or as a damp solid. Ferric sulfate is available as a commercial coagulant and has the advantage of being less corrosive than ferric chloride.

Ferric salts are used for the following reasons:

1. Ferric floc is heavier than aluminum floc and settles more readily. It is also more completely precipitated over a wider pH range.
2. Ferric floc does not redissolve at high pH when lime is used for corrosion control.
3. Ferric floc forms more rapidly in cold water than does alum floc.

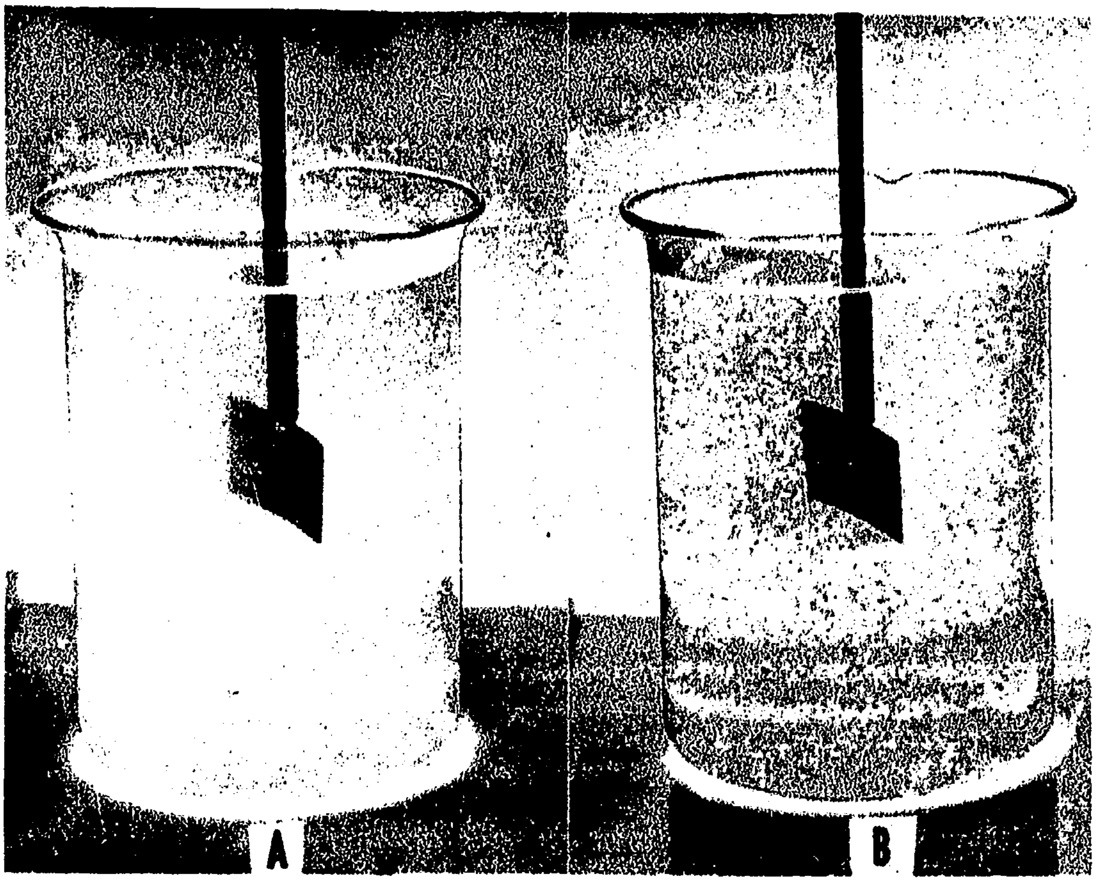

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Figure 9-2.—Effect of coagulant aid on floc formation. (A) Without coagulant aid. (B) With coagulant aid.

4. Ferric coagulants are effective in color removal in alkaline waters with pH value over 9.0, and in iron and manganese bearing waters when used with lime to produce a pH value of 9 to 9.6.

Coagulant Aids

A single coagulating chemical is often sufficient to produce good results. However, if the characteristics of the water create a difficult coagulation problem, there are available several materials which will improve the effectiveness of the coagulation process or speed the settling of the floc when used in addition to the coagulant chemical. The effect of a coagulant aid on flocculation is shown in figure 9-2.

Chiefly used among the coagulant aids is activated silica, or sodium silicate treated with aluminum sulfate, chlorine, ammonium sulfate, or carbon dioxide. The mixture must be aged 10 minutes or more. The use of this chemical results in the formation of a dense, heavy floc, which is especially valuable in treating water low in suspended solids.

A number of compounds, classified as polyelectrolytes, have lately become commercially available as coagulant aids. These are complex organic compounds and are usually synthetic. They may be anionic in character (negatively charged) or cationic (positively charged) or nonionic (neutral). Since all polyelectrolytes are not equally effective with all waters, a degree of experimentation is desirable. The toxicity of commercially prepared products is studied by a technical advisory committee of the U. S. Public Health Service that reviews the matter of toxicity of compounds as they are submitted by manufacturers. Only those compounds which have received clearance by this agency shall be employed in the treatment of potable water.

Several commercial clays have been found to aid in "weighting" floc so as to speed settling. Samples for testing their applicability for coagulation of a particular water may readily be obtained from manufacturers or local suppliers.

Determination of Chemical Dosage

Many factors influence the type and amount of chemicals required for effective coagulation of raw water. Dosages of chemicals required vary greatly, from as low as 1 ppm to more than 100 ppm. Jar tests, laboratory scale coagulations, are usually carried out on the raw water to obtain information as to the kind and quantity of chemicals to use. It then remains to modify the jar test results by trial runs in the plant to find the exact dosage required to obtain the most economical results. It is usually more efficient to run jar tests than to experiment in the treatment plant. Every water treatment plant requiring coagulation should make at least one jar test daily to determine or to check the chemical dosages required. Control tests for coagulation processes are covered in chapter 10.

CHEMICAL FEEDING EQUIPMENT

The amounts of chemicals added to the water must be carefully controlled to ensure uniform treatment. Many types of chemical feeders, manually or automatically controlled, are available. However, dry feeders (covered in chapter 8) are most often used because of their greater accuracy and simpler operation.

FLASH-MIXING

The more quickly the coagulants can be uniformly mixed with water to be treated, the more rapidly and completely will the chemical reactions take place. In water treatment practice, this is called rapid or flash-mixing. The compartment in which this process takes place is known as the mixing chamber or basin. The devices by which rapid mixing is accomplished are known as rapid flash-mixers. These include pumps, aero-mixers, turbo-mixers, air-agitated mixing chambers, and mechanical stirrers. (See fig. 9-3.) Some mixing will also take place in the pipes and conduits through which water flows.

FLOCCULATION OR FLOC CONDITIONING

The process of flocculation, which follows the addition and mixing of the coagulant, is to promote the growth of the floc particle and to provide opportunity for contact between the floc and the suspended particles causing turbidity.

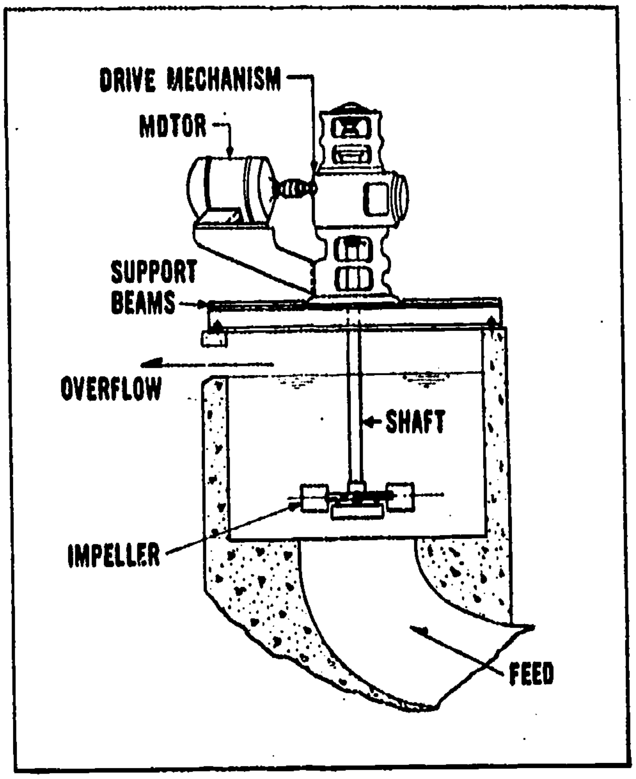

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Figure 9-3.—Flash mixer.

The increased weight of the floc results not only from the increased size of the floc but also from the adsorption of turbidity particles on the enlarged precipitate as it moves through the water. The more opportunity floc has to contact the suspended turbidity, the more efficient is the removal. Floc increases in size through the action of gentle stirring, and contact between the floc and turbidity is promoted by allowing low enough velocities through the flocculation chambers and furnishing a long path of travel. Too much agitation will break up the floc.

FLOCCULATING EQUIPMENT

While individual installations may vary, most flocculation equipment is of one of three types—baffle basins, power-driven paddles or agitators (rotary and walking beam), and spiral-flow flocculators.

Baffle basins are the oldest method, and as suggested by the name consist of tanks with baffle walls built in them to turn the water. The baffles may be of the "over and under" type, or the "end around" type. The passageways formed by the baffles constrict the flow

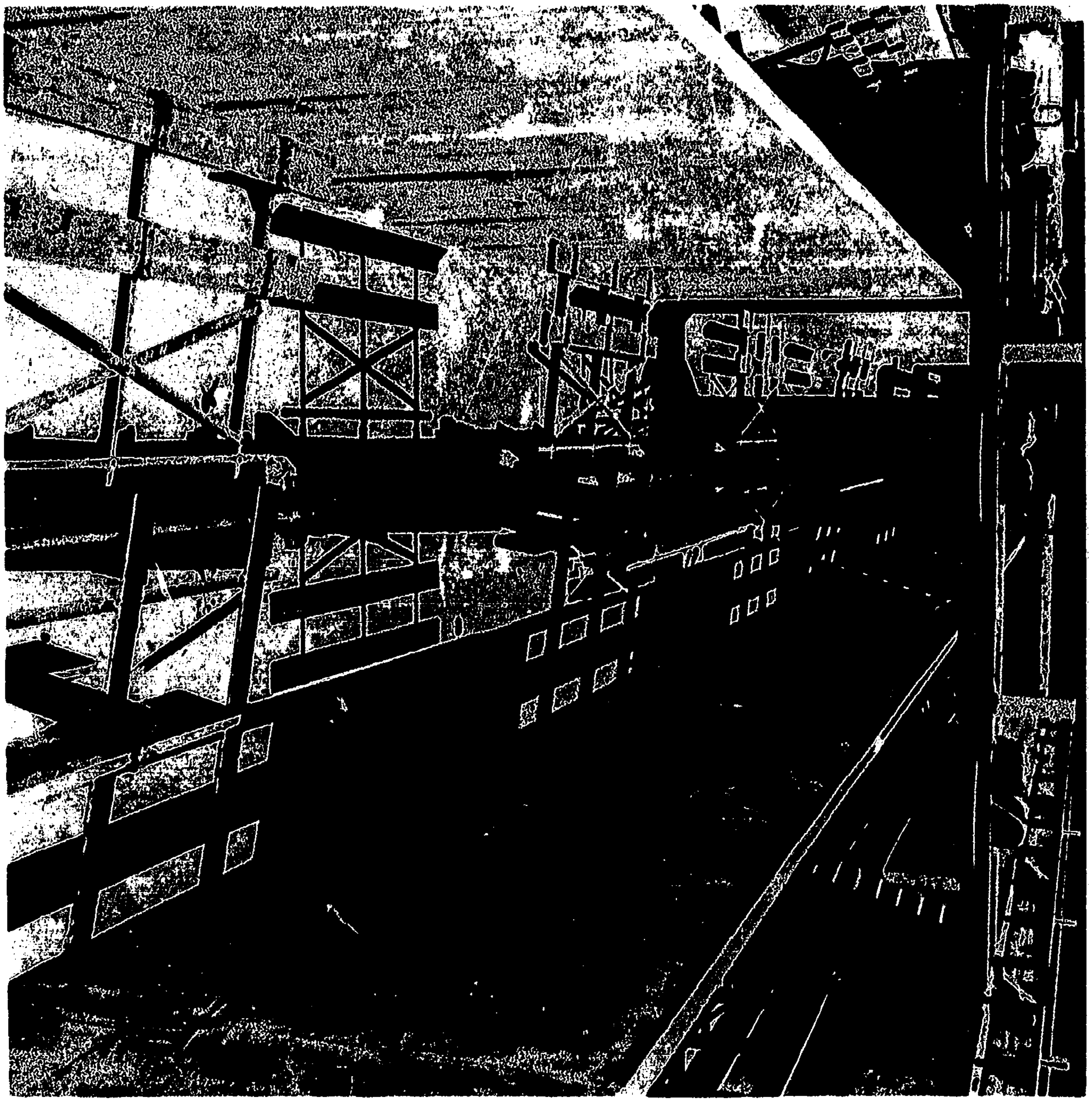

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Figure 9-4. —Rotating paddle flocculator.

so that increased velocity is set up, and in going around the baffles, the water is "turned over on itself."

The paddle-type (rotary type) flocculator consists of a mechanical tank with a paddle-like stirrer which imparts a velocity to the water. The area of the paddles is usually from 10 to 25 percent of the cross-sectional area of the tank (see fig. 9-4). These mechanical devices are used to achieve slow or gentle stirring and to provide a long path of travel for the floc. The paddles, usually of steel or wood, are generally mounted on a steel frame revolving on a horizontal axis, the vertical dimension of the frame being slightly less than the depth of water. The rotating unit may be mounted so that the axis is either parallel or perpendicular to the direction of the flow of water. Normally there are three to four units in a row, and three to four rows in a series, as may be required.

The "walking-beam" type of flocculator provides the same primary functions as the rotary type, but by a different mechanism. This flocculator applies the stirring action by means of an up-and-down motion of paddles mounted on triangular forms at the bottoms of long vertical arms.

The spiral-flow flocculator consists of a circular or square basin of such a design that the water enters tangentially so as to cause spiral flow. Usually the effluent pipe leads from the center and upper portion of the basin so as to ensure this spiral flow and to prevent short-circuiting of the water being flocculated. Appreciable agitation in the basin can be assured by proportioning the inlet to secure a velocity of 2 to 3 feet per second for the entering water. These tangential flow basins are well adapted to small filtration plants, and also as additions to existing plants where only a limited head is available to provide needed agitation.

CLEANING FLOCCULATORS

Generally, flocculators are cleaned at 3- to 6-month intervals, or when development of an odor or a tendency for floc particles to rise to the surface indicates that septic sludge conditions are developing. Copies of the manufacturer's instructions should be kept available for ready reference. Personnel must thoroughly familiarize themselves with the equipment so that repairs may be made quickly and properly.

FLOC SETTLING

The process of floc settling is accomplished in basins designed to produce sufficiently low water velocities so that the floc can settle out quite completely in the time allowed for the water to pass through the basin. Correct basin design keeps the water from flowing directly from inlet to outlet, and distributes the flow uniformly throughout the cross-section of the basin. A uniform velocity of no more than 1 foot per minute is desirable.

SEDIMENTATION BASINS

The main items in the operation of sedimentation basins are the control of the quantity

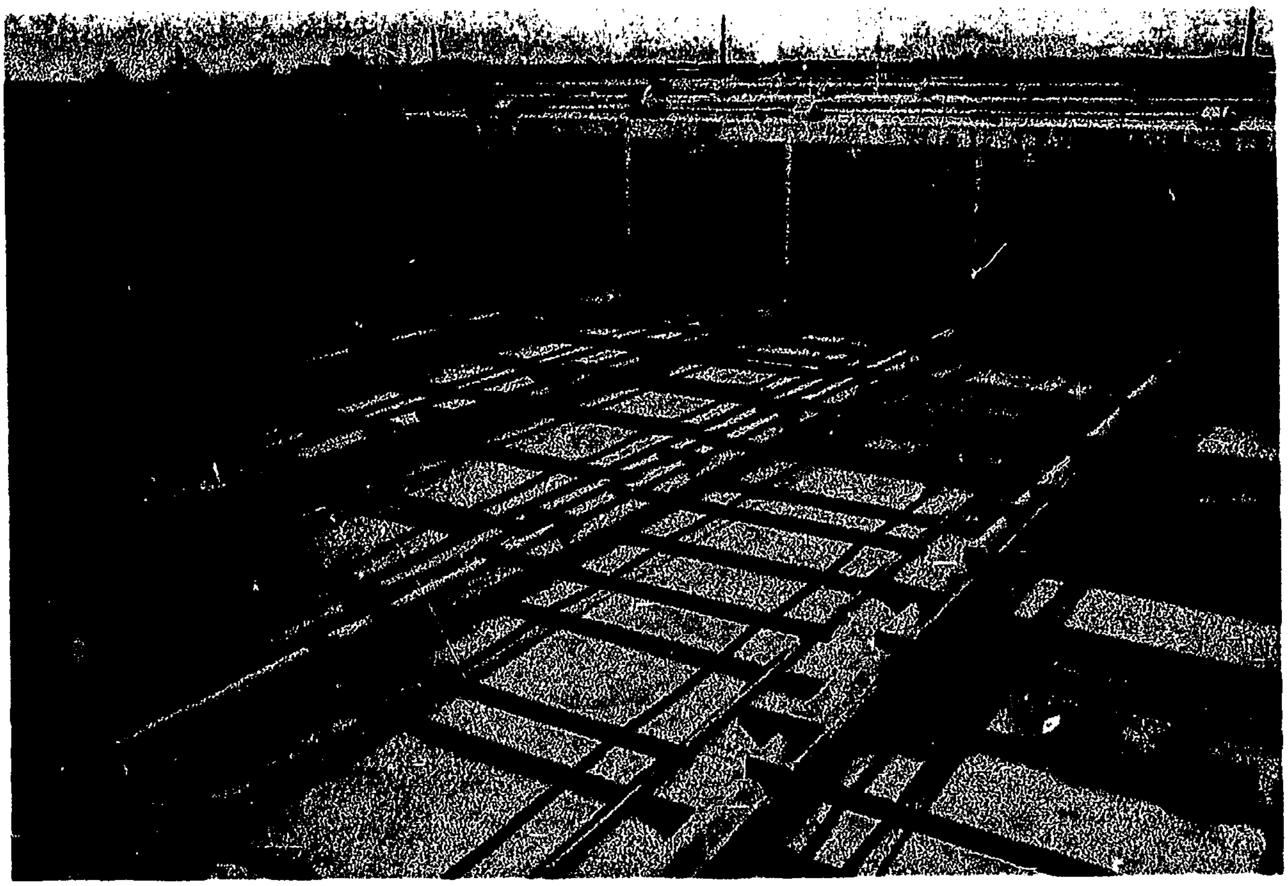

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Figure 9-5.—Sedimentation basin showing longitudinal sludge collector system utilizing flights on chains.

of water flowing through the basin; the removal of sludge from the basin; and the cleaning of the basins and the sludge collecting equipment. Figure 9-5 shows a sedimentation basin which utilizes longitudinal sludge collecting flights.

Control of the quantity of water flowing through the sedimentation basin is accomplished by the use of plant metering devices or by periodic checking of the discharge rate of the raw water pumps. In cases where the raw water enters the plant by gravity flow, an orifice plate, venturi tube or other type of meter, and a control valve are used so that the flow-through quantity can be accurately determined and controlled.

Detention periods of 4 to 6 hours are commonly used in sedimentation basins. There are several practical methods of estimating this detention time, including the use of dyes, confetti, submerged floats, and a salt solution.

Studies with the use of dyes have shown that a portion of the entering water may pass through the basins in less than 15 to 25 percent of the computed detention period, whereas other portions of the water may remain in the basin for periods well in excess of the computed period. While the use of dye is very helpful in indicating the existence of serious short-circuiting and just where water may be passing through the basin at a high rate, eventually dye diffuses throughout the water in a basin and further observations are not feasible. In the absence of other means, however, the use of dye is very helpful in disclosing where short-circuiting is occurring. Observation of eddies that result in short-circuiting in sedimentation basins may also be made with confetti. A small handful of confetti is dropped into the stream of water entering a basin at intervals of 5 minutes so as to disclose the direction and the velocity of the currents. The three-dimensional appearance of the batches of confetti also makes observation of vertical eddies possible.

Submerged floats with an above-the-water flag or target will indicate the direction and rate of movement of water through a basin. The floats should have a large area to make them respond to slow velocity currents, and their depth of submergence should be as representative as possible. Floats are particularly useful in the study of large open basins or reservoirs.

The most accurate procedure for measurement of detention time is with the use of salt solution. This consists of the application of a strong solution of salt to the influent of the sedimentation basin in a quantity necessary to produce a dose of about 3 ppm (in terms of chlorides) for a period of 5 minutes. Immediately upon the application of salt to the influent, samples of water should be collected from the effluent of the basin, and this should be repeated at intervals of 5 minutes so that subsequently the chloride content of the series of samples may be determined. These samples will reveal when a portion of the salt-treated water has reached the outlet end of the basin; when the maximum concentration of salt has reached the effluent end of the basin; and, when the last trace of salt has disappeared from the basin, as shown by the return of the chloride content to normal.

SLUDGE REMOVAL

Sludge removal from sedimentation basins may be either intermittent or continuous.

For sedimentation basins not equipped for continuous sludge removal, it is necessary that an adequate number of drain valves be provided and properly spaced over the bottom of the tank. These valves are opened periodically and the sludge removed by gravity drainage.

Continuous removal of sludge has been found to be more satisfactory and efficient, particularly where there is a considerable amount of sludge to be removed. It is considered essential in modern design practice. Square and round sedimentation basins are usually equipped with a spiral rake in the bottom of the tank that rotates and moves the sludge to the sludge drain in the center. The tank bottom is sloped toward the center to assist in moving the sludge toward the drain. For rectangular basins, scrapers are provided that are dragged along the floor of the basin, carrying the sludge to sludge hoppers located at the bottom of the inlet end of the tank (see fig. 9-6). From these hoppers, the sludge is removed either by gravity or by pumping to a disposal area.

In some cases where sludge is removed continuously, it has been found desirable to return a part of the sludge to the raw water as it enters the mixing basin. This returned sludge aids coagulation and increases the rate of settling, adding bulk to the new floc being formed and making it more effective and more rapidly settling.

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Figure 9-6. — Sedimentation basin with longitudinal sludge collector system using sludge rakes.

Whenever any foreign objects are dropped into the tank which could injure the sludge collecting mechanism, the mechanism must be stopped immediately and the objects removed.

CLEANING

Sedimentation basins are cleaned at about 3-month intervals, or whenever development of an odor or rising floc particles indicate development of septic sludge conditions. Basins with mechanical equipment for removing settled sludge usually clean themselves satisfactorily during normal operations. However, it may be necessary at times to drain them, and to clean the tank and mechanism with a high-pressure water hose.

The depth of deposited sludge at various places in the basin should be observed from time-to-time to ascertain the points where sedimentation is most effective and also when the basins should be cleaned. These observations may be made by attaching a wooden rod at right angles to the center of a lightweight board structure about 2 feet square, so that this flat surface may be slowly lowered until resistance is offered by the sludge. Obviously, the upper portion of the sludge deposit has little consistency and, therefore, will not be felt with this device. Nevertheless, the upper level of the solidified sludge will be quite apparent.

If the plant has mechanical sludge collectors, keep a copy of the manufacturer's instructions at hand for ready reference. Operators must be completely familiar with mechanical appliances and instruction books so that emergency repairs can be made quickly and correctly.

FILTRATION

Water from the settling basins is brought to the filters as the next step in the purification process. This water contains very finely divided suspended matter such as minute particles of floc, clay, and mud that has not coalesced, and bacteria and microscopic organisms that have not been removed by settling. The purpose of the filter is to remove this last portion of suspended matter so as to give the final treated water a clear, sparkling, and attractive appearance.

The efficient operation of a filter depends upon effective pretreatment of the water; proper washing of the filter; special cleaning of the filter medium when necessary; and maintenance of rate controllers, loss-of-head gages, underdrains, and valves in a satisfactory operating condition. A filter consists of a bed of carefully sized and washed sand or other filter medium, such as screened and washed anthracite coal, supported by graded gravel. The gravel rests on an underdrain system of filter bottom (see fig. 9-7). The removal of suspended and colloidal

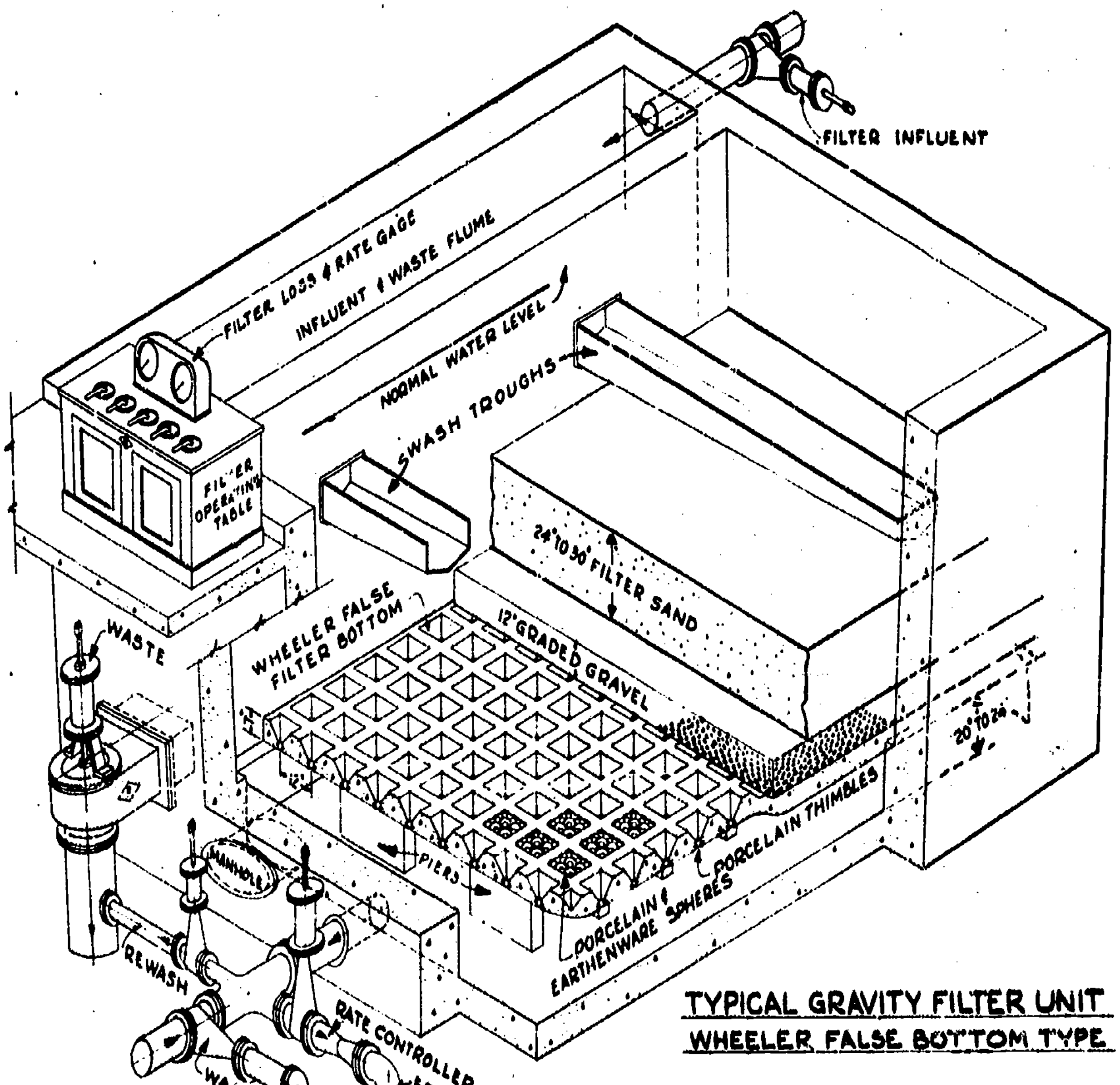

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Figure 9-7. —Diagram of filter installation with Wheeler filter bottom.

matter may be accomplished in several ways, as discussed in the following paragraphs.

STRAINING: When first placed in use, a clean filter will remove only that material larger than the opening of the pores. As this action progresses, a mat is formed on top of the sand; smaller particles are removed by this mat, and more efficient clarification is obtained. This straining action takes place on or near the surface of the filter sand. The thin surface mat of fine sand, floc particles and other fine solids which do most of the filtering job is often referred to as the "schmutzdecke" (German for dirt layer).

SEDIMENTATION: Particles smaller than the pore spaces tend to settle out within the pore space, because of the relatively large volume of these voids in a filter medium. They act as minute settling basins and, therefore, tend to remove suspended matter.

FLOCCULATION: Colloidal floc formulations may carry over from the sedimentation basin

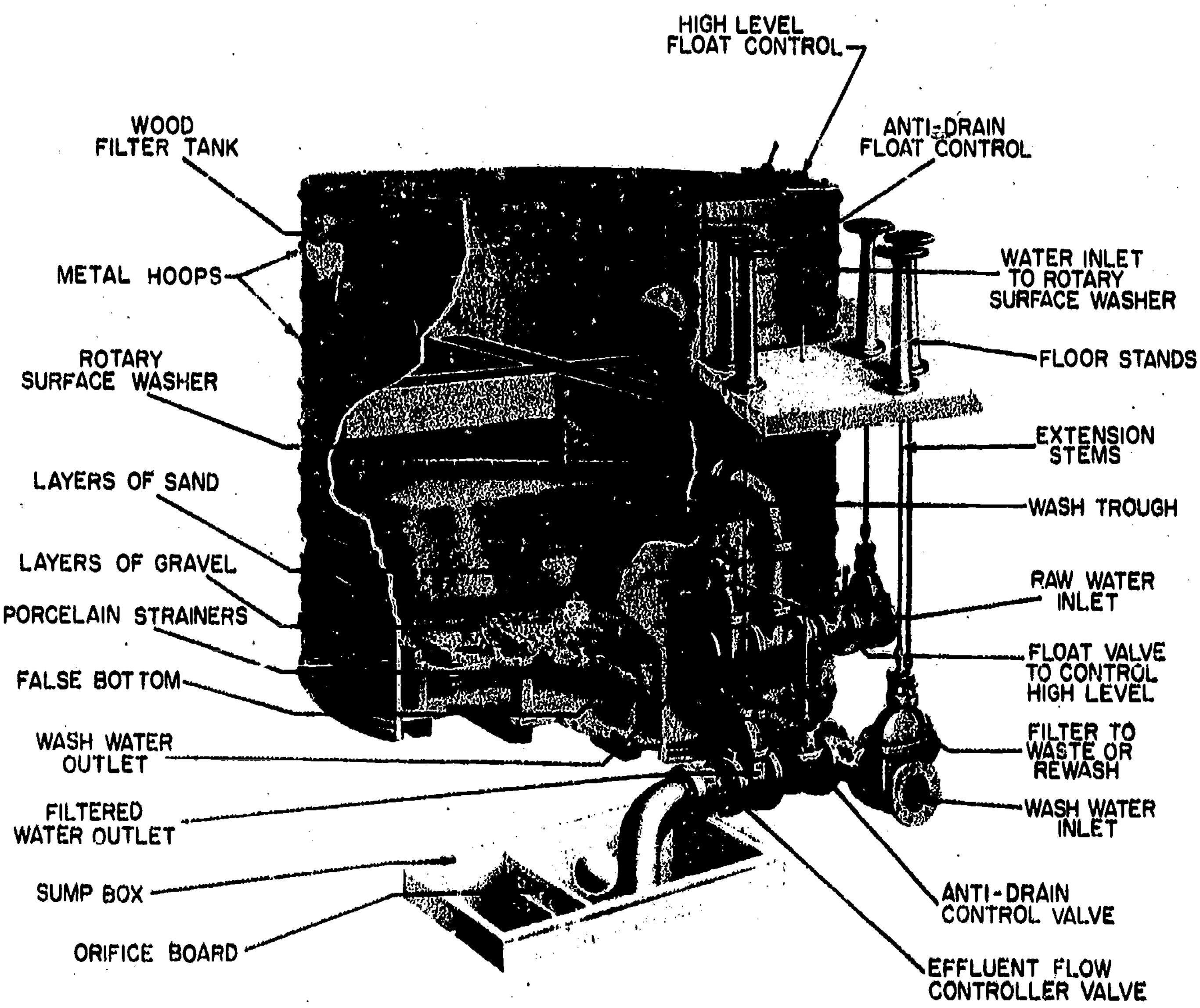

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Figure 9-8.—Cutaway view of gravity sand filter with rotary surface wash.

and continue to coalesce and grow in passageways between the medium grains and become large enough to be retained. This offers further opportunity for other impurities to become entrapped. Also, this action will usually increase pore velocities, which in turn tends to carry floc particles further into the bed helping to build up head loss in the filter. The filter will eventually have to be backwashed to restore it to full filtering capacity. Most foreign matter is removed in the top few inches of the sand bed. However, to prevent any material from passing through the filters, sufficient depth of filter media (24 to 30 inches) and restricted filter rates must be maintained.

TYPES OF FILTERS

In modern water works usage, two principal types of filter are used—rapid sand filters and diatomite filters. A third type, the slow sand filter, is seldom used in modern installations. Diatomite filters are primarily used in swimming installations and in advanced base water supply systems. Only in exceptional cases and when approved by the Naval Facilities Engineering Command are diatomite filters used in the treatment of potable water at permanent naval shore activities.

Rapid Sand Filters

There are two types of rapid sand filters—gravity and pressure.

The gravity type of filter is essentially open-top, rectangular concrete or wooden boxes about 10 feet deep (see fig. 9-8). An underdrain system at the bottom is covered with graded gravel, which in turn supports a 24- to 30-inch layer of filter sand. Gravity filters are usually

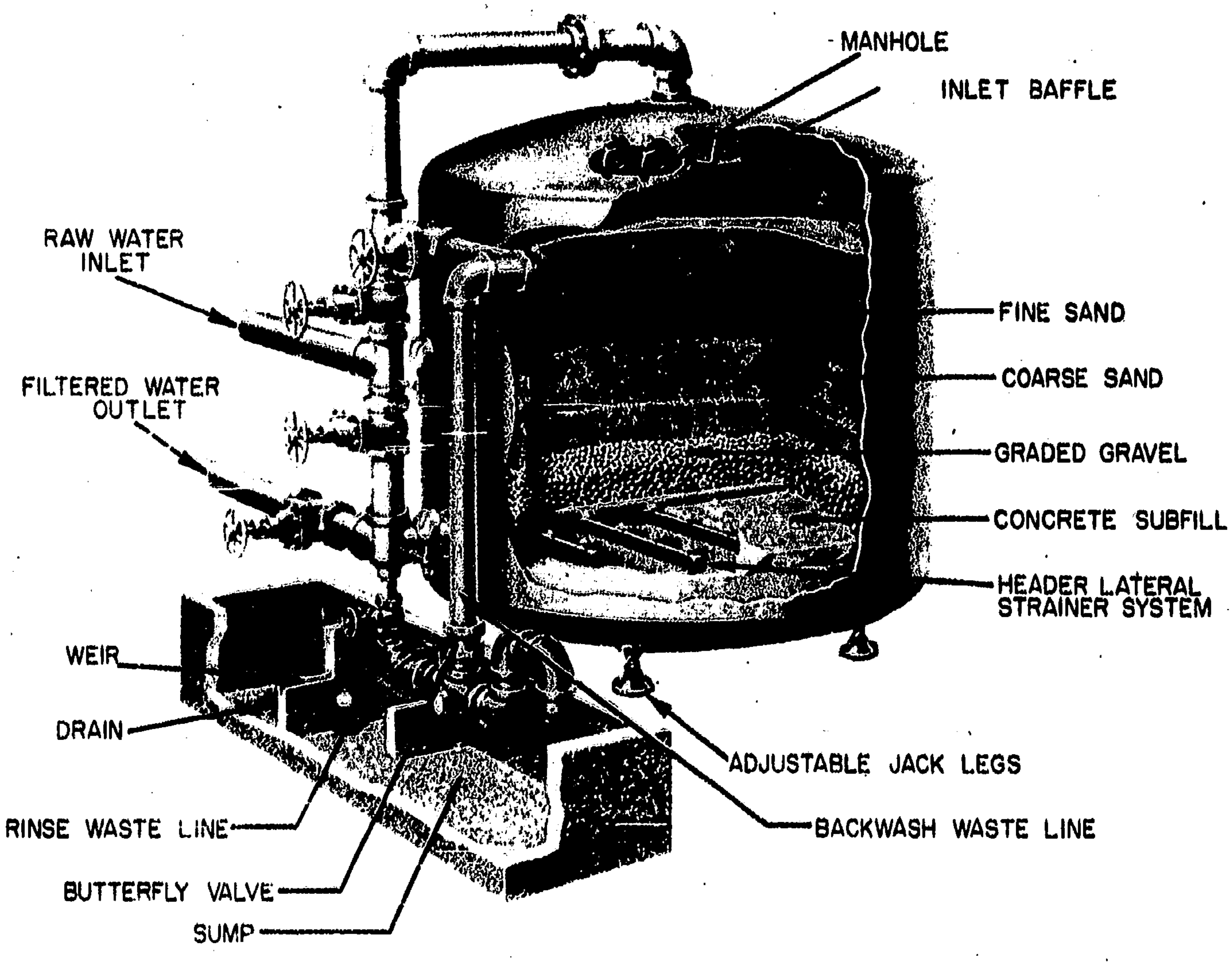

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Figure 9-9. — Pressure-type rapid sand filter.

designed to filter at about 2 gpm per square foot of filter bed area. However, in an emergency, up to 4 gpm per square foot can be obtained with a properly coagulated water.

The pressure type of rapid sand filter consists of a filter bed in a closed tank. Water is pumped through the filter under pressure. A pressure filter can be installed with the tanks set either vertically or horizontally and operates on the same principles and at the same rate as gravity filters (see fig. 9-9).

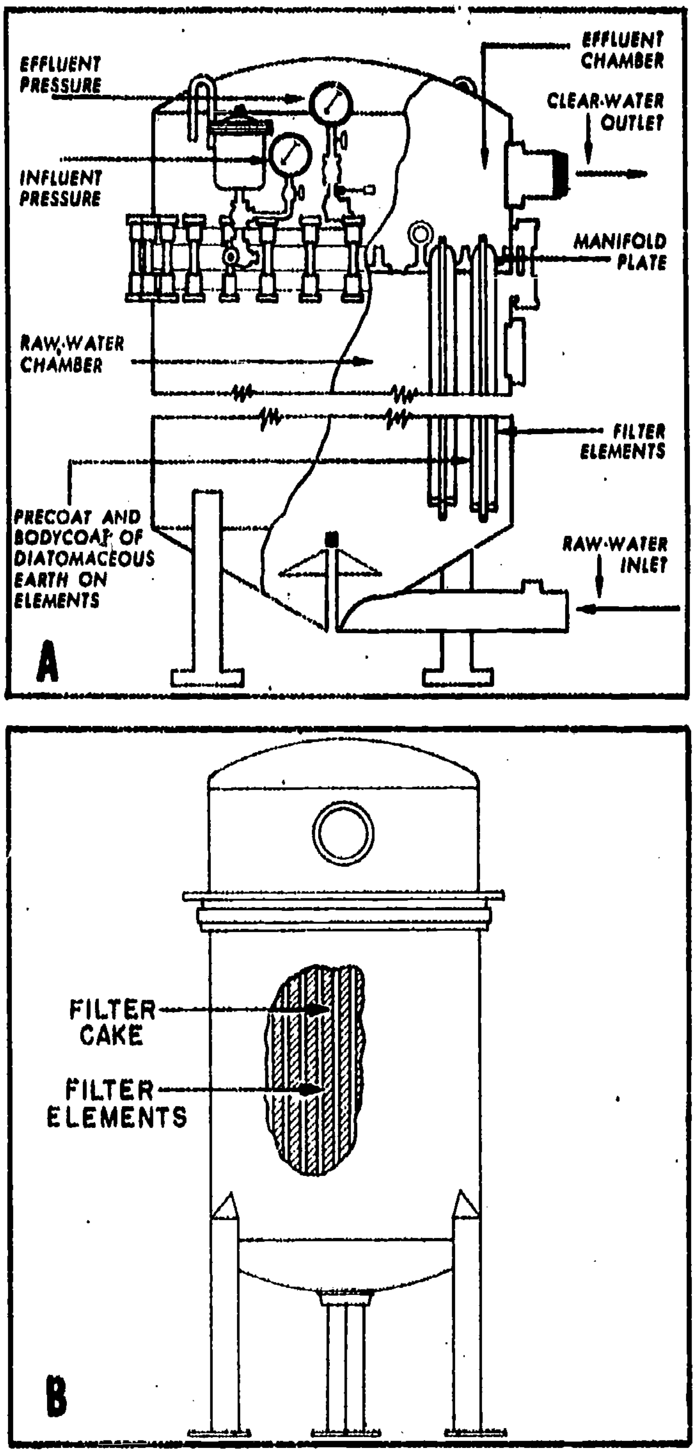

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Figure 9-10.—Pressure-type diatomite filter (two views).

Diatomite Filters

The diatomite type of filter is a special pressure (or vacuum) filter which uses a porous mineral powder, known as diatomaceous earth, as the filter medium for the removal of suspended materials from water. The pressure-type diatomite filter, used in swimming pools and advanced base water supply systems, consists of a tank-like steel shell supporting a series of cylindrical filter elements on which a layer of diatomaceous earth is built up. (See fig. 9-10). These elements may be wire-bound plastic or steel cores, metal screen mesh, sintered brass, porous stone, or Carborundum.

FILTER MEDIA

Materials now employed as filter media include sand, anthrafilt, and diatomite.

Filter SAND is composed of sharp or rounded durable grains of clean silica, such as quartz or quartzite. A filter sand is acceptable under the following conditions:

1. When powdered and left for 24 hours in a warm bath of 20 percent hydrochloric acid, it does not lose more than 5 percent of its original weight.
2. When heated to over 700° C, it does not lose more than 2 percent of its weight.
3. Its effective size must be between 0.35 and 0.70 mm and the sand must have a uniformity coefficient of 1.5 to 1.6. The effective size of a filter sand is that grain size which is smaller than 90 percent (by weight) of the grains in the sand and larger than 10 percent. This characteristic is used as an index of a sand's filtration rate. If a sand were regarded as being made up entirely of the effective size grains, the filtration rate would be the same as for the original sand. Effective size equals the rated size of opening (in mm) of a sieve that passes 10 percent by weight of the filter sand.

ANTHRAFILT is a filtering medium obtained from carefully selected, cleaned, and screened anthracite coal. It is acceptable under the following conditions:

1. It must be dirt free.

2. The effective size must be 0.65 to 0.73 mm.
3. It must have a weight of about 53 pounds per cubic foot.
4. The ash content may not be over 11 percent.

DIATOMACEOUS EARTH has the physical appearance of white face powder or finely milled white flour. It is very light and has great bulk per unit of weight. Diatomaceous earth is available from several manufacturers in various grades (particle size) for different uses.

FILTER GRAVEL

Gravel in a filter has three main functions. It supports the sand, permits water to flow freely to the underdrain, and aids in distributing wash water to all parts of the sand uniformly.

Gravel is usually placed in the filter in graded layers, with the coarsest grade on the bottom and the finest on top. When the filter is in use, a 27-inch total depth of gravel may shrink to as low as 18 inches.

Unequal distribution of wash water sometimes results in a jet action that may cause the top layer of gravel to become uneven and mounded. Adding a 4-inch layer of coarse sand on top of the graded gravel helps stop the mounding.

UNDERDRAIN SYSTEM

Underdrains provide an outlet for water passing through the filter and are also the means of supplying wash water to the underside of the beds (see fig. 9-11).

The PIPE type of underdrain system consists of a cast-iron manifold or header with laterals usually on 6-inch centers. The laterals are closed at the outer ends, but have orifices drilled in the underside. Total area of all orifices is about 33 percent of the area of the filter surface.

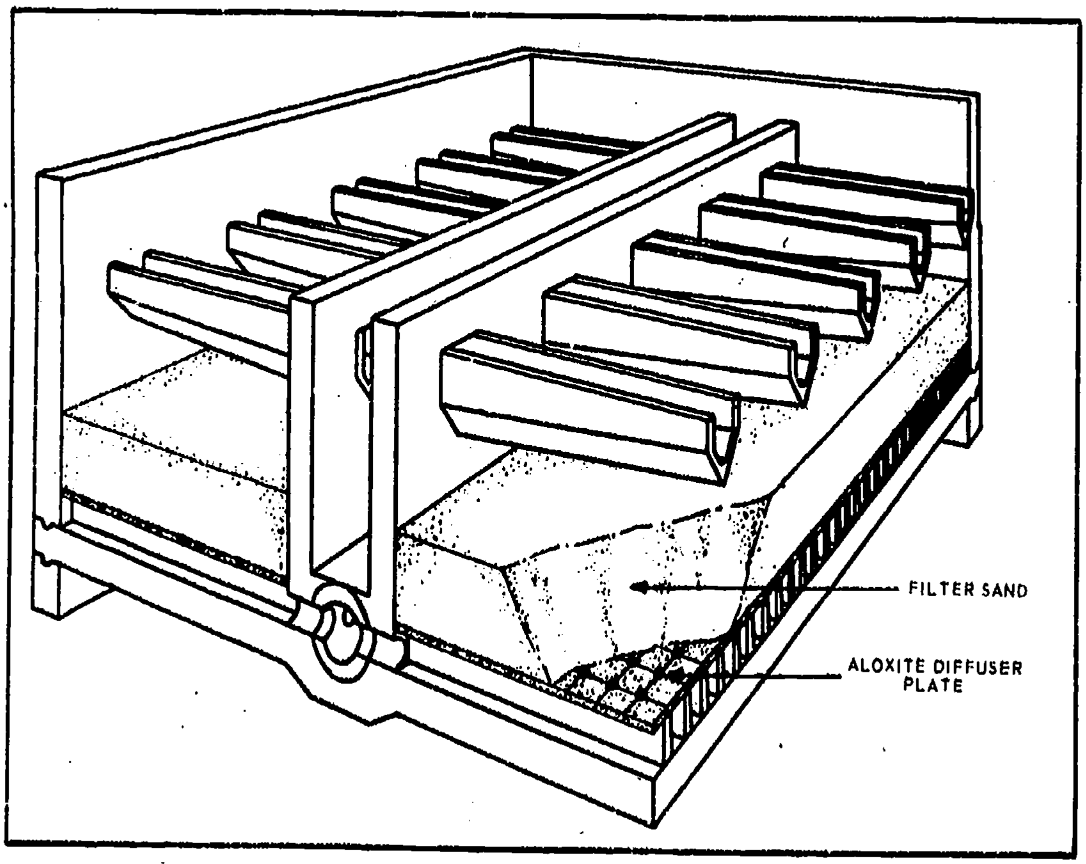

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Figure 9-11.—Filter underdrain system.

Various types of FALSE BOTTOMS are also used as underdrains. Some of these are assembled from specially designed perforated clay tile sections, others from sections of porous Carborundum or similar materials, and still others may be largely cast-in-place concrete.

FILTER EQUIPMENT

Filter equipment includes the rate controller, loss-of-head gage, wash-water controller, rate-of-flow indicator, hook gage, piping, and valves.

When a filter bed is first put into operation or has just been washed, water passes through it far too quickly for efficient filtration, unless the filtering rate is controlled. Therefore, the effluent line must be throttled to reduce the rate of flow. As the filter bed becomes clogged, the rate of filtration decreases and the amount of throttling must be reduced accordingly to keep the rate of filtration uniform. Manual control of the filter rate is impractical, so the rate of flow controller must be used. A cutaway view of a filter rate controller is illustrated in figure 9-12. An installation view of a rate controller is shown in figure 9-13.

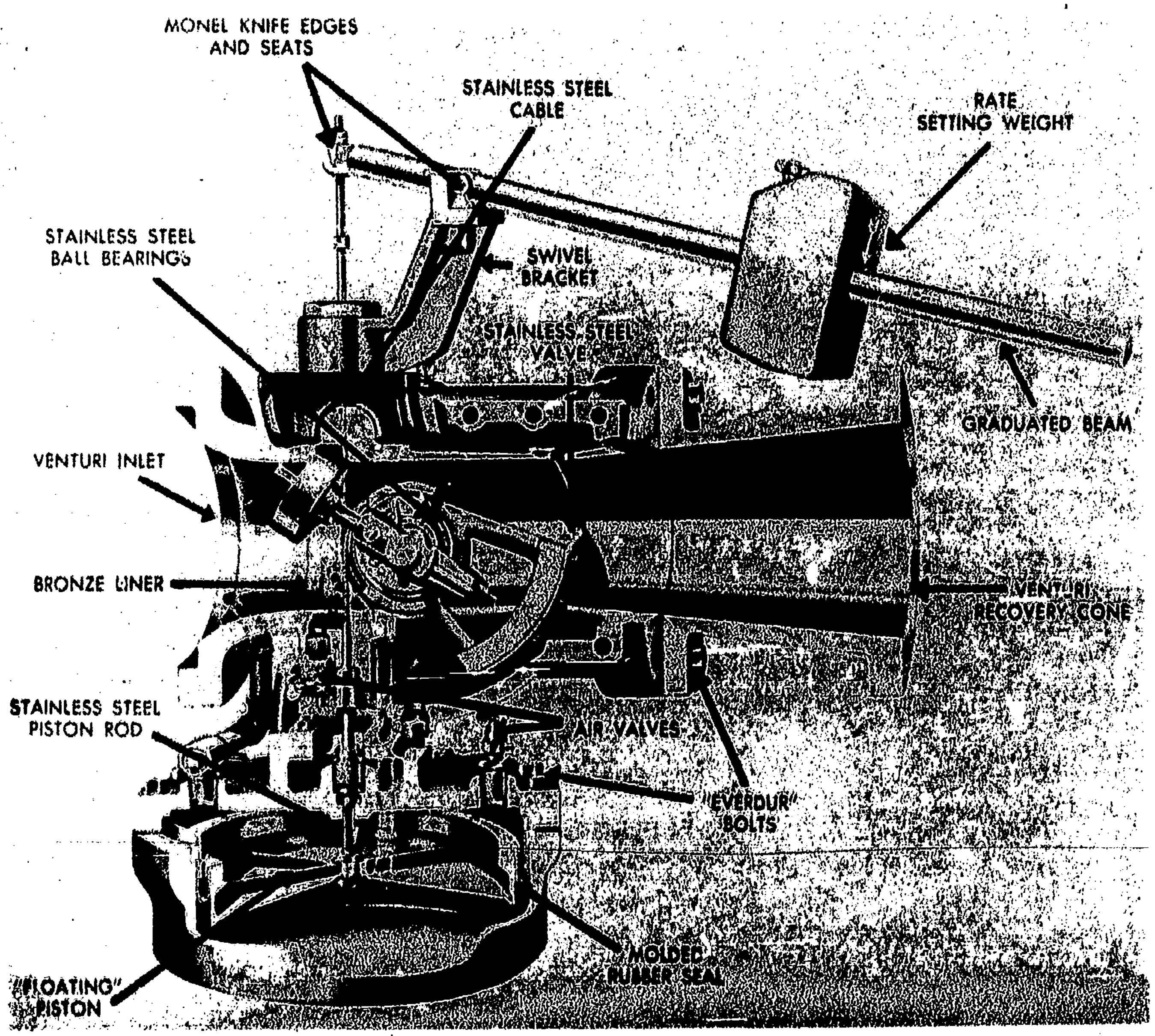

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Figure 9-12.—Cutaway view of filter rate controller.

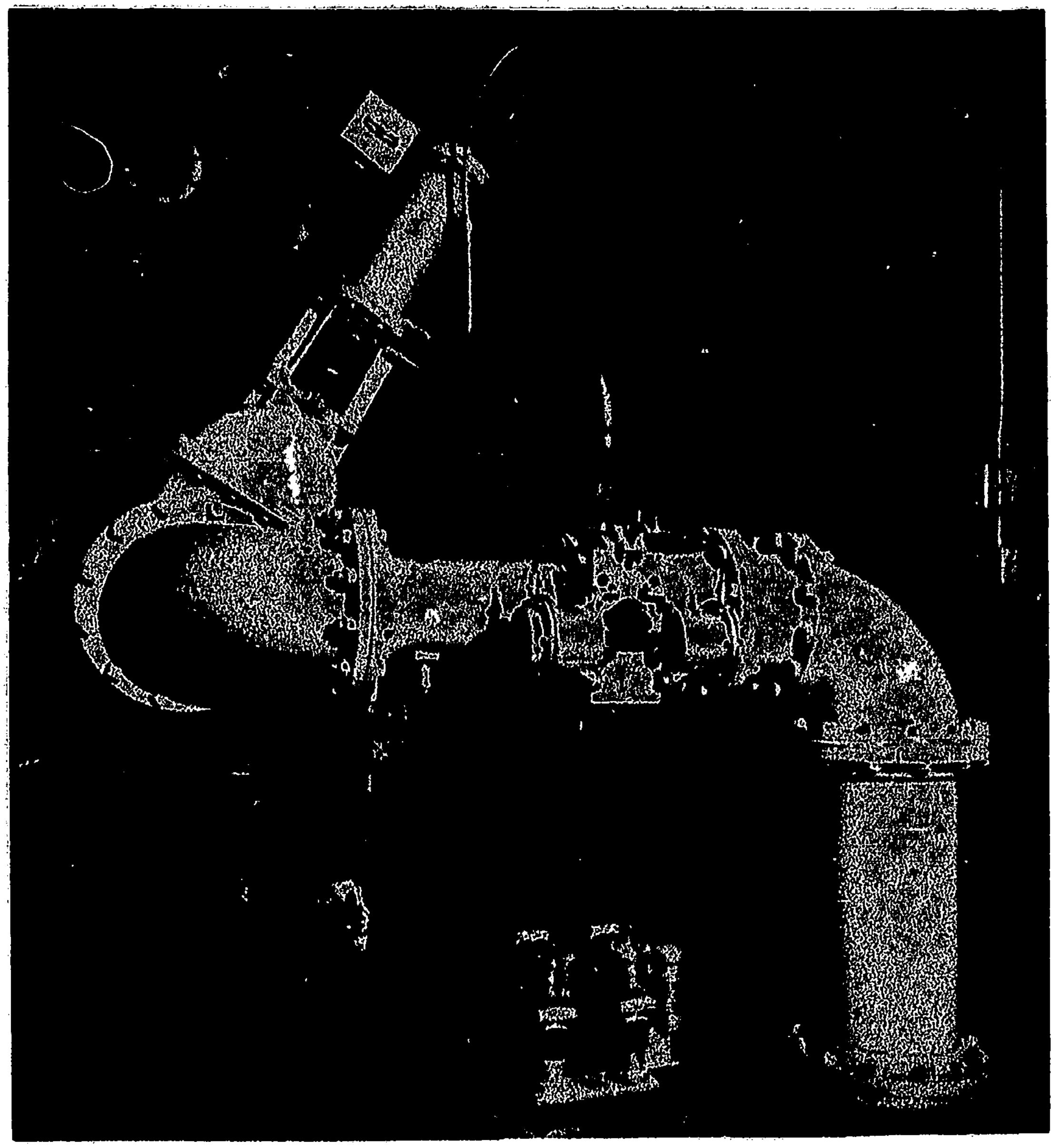

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Figure 9-13. —Installation view of rate controller.

The loss-of-head through a filter is the friction loss of the water through the sand bed and underdrains of the filter. It is measured as the difference between the surface elevation of the water on the filter, and the static operating level of the water in a vertical tube on the discharge pipe of the filter. The loss-of-head gage is operated by two floats, one at the surface of the water in the filter and the other at the static operating level of the water in the main underdrain pipe. The loss-of-head gage (see fig. 9-14), which measures the difference between the two elevations, is the most important guide to filter operation.

Wash-water controllers are considered an essential part of a modern filter plant. A rate-of-flow controller similar to the one controlling the filtering rate, a butterfly valve or a special type plug valve may be used to control the wash-water rate. The valve operation mechanism, or control, and a pressure gage showing the pressure in the wash-water pipeline on the discharge side of the control valve should be located on the operating floor.

A rate-of-flow indicator measures the rate of water production by the filter. It usually consists of a venturimeter in the filter effluent line operating an indicating instrument located on the operating floor where it can be readily seen by the operator. In some types of plant equipment, it is combined with the loss-of-head gage and the rate-of-flow controller metering devices.

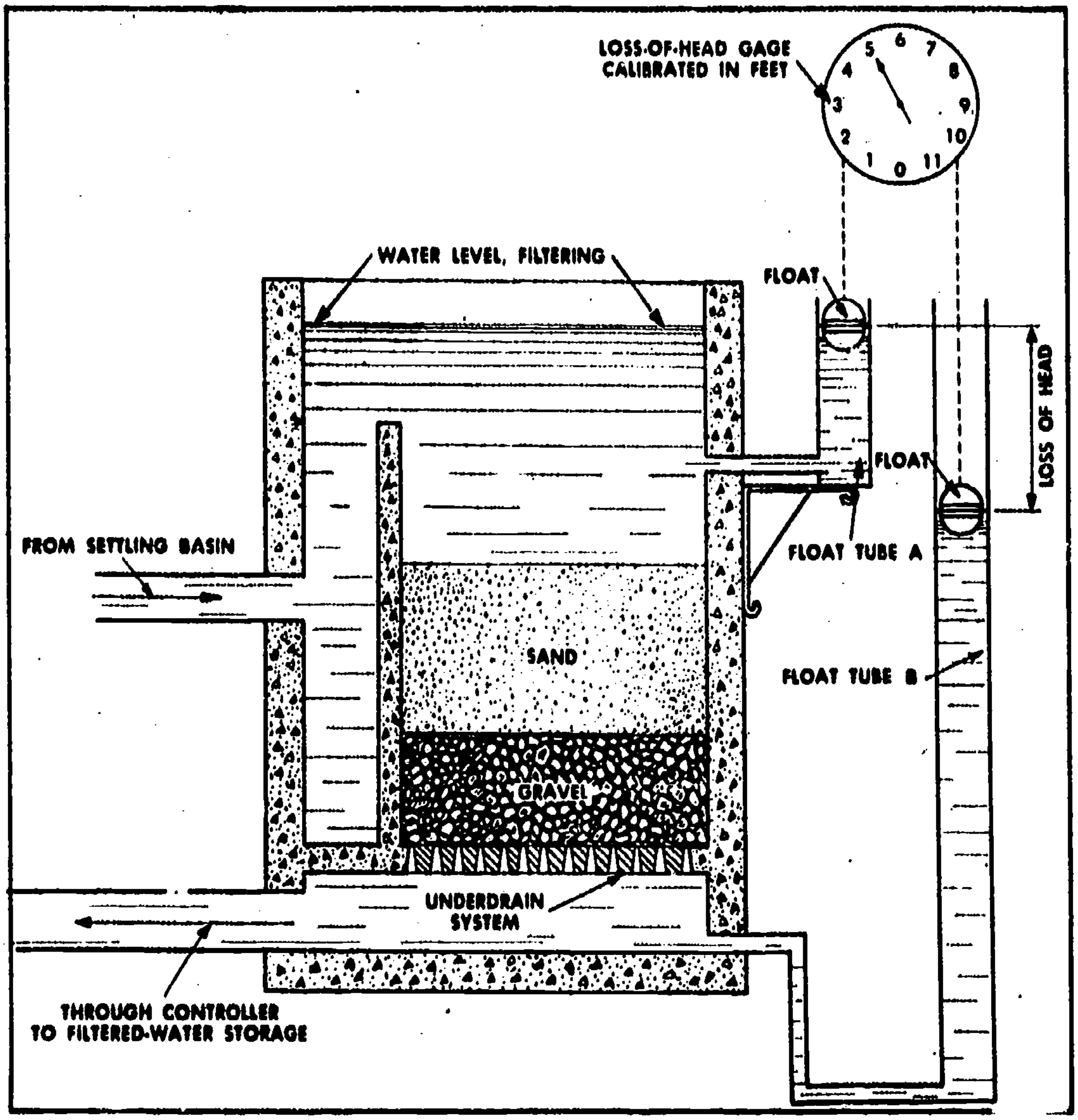

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Figure 9-14.—Loss-of-head gage.

A hook gage is a series of vertical sharp pointed rods held in a frame which may be hung on the side of the filter (see fig. 9-15). The tips of the sharp pointed rods are set accurately at 2- to 3-inch spacings. It is used by the operator to check the rate of filtration and washing by observing and recording the time required for the water level to rise or fall between the points. The volume of water in the filter between the gage point levels is easily calculated, and from the recorded time, the rate is readily and accurately determined.

Filter piping is usually located in a pipe gallery and carries the influent, effluent, wash water and waste water to and from the filters. Valves and piping are so arranged that some of the piping may be used for more than one purpose. The rate-of-flow controllers and metering units are installed in the pipelines to which they apply. Valves may be operated manually, electrically, hydraulically, or pneumatically. Sampling taps and air cocks for release of trapped air are usually provided. Because of expansion and contraction, at least one sleeve joint should be provided in each pipeline at each filter. The pipe gallery should be well lighted, well ventilated, and provided with a floor drain or sump pump. All piping and valves should be kept painted at all times in order to minimize external corrosion.

OPERATION OF SAND FILTERS

An influent pipe carries the partially clarified water from the sedimentation basin to the filter bed, discharging behind a baffle wall ahead

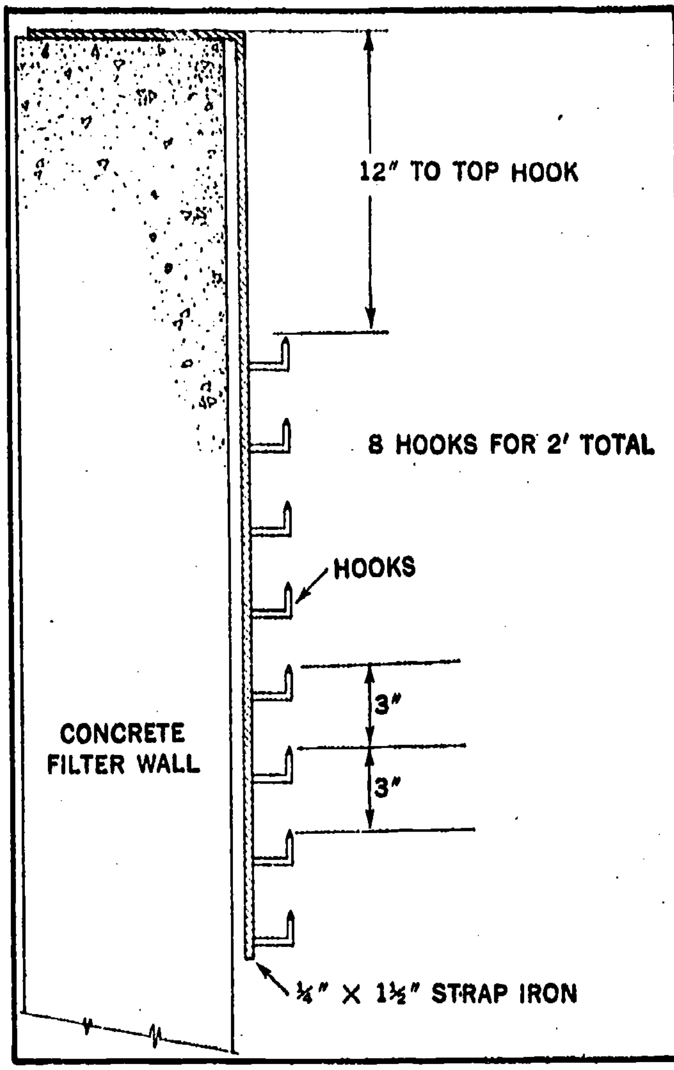

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Figure 9-15. —Hook gage.

of the filter bed or by overflowing distribution troughs so that water currents do not disturb the sand bed. The water filters downward through the sand and gravel into the underdrains, passes through a rate controller, and is collected in a filtered-water reservoir called a clearwell.

When the loss-of-head gage shows that the filter is becoming dirty or clogged, the filter must be washed. This is done by reversing the flow through the filter in order to remove the accumulated material on the filter and to carry it to waste through the plant sewer.

FILTER RATE CONTROL

A constant and controlled rate of filtration is necessary because changes in the filtering rate may cause breaks in the schmutzdeck, allowing the water to pass through the bed without being filtered. Also, a decrease in the pressure under the filter surface may cause dissolved gases to be released from the water, thereby causing the filter to air-bind.

There are two essentials in the control of the filtering rate. An adequate supply of influent water is required to meet the desired rate; and the total filtering rate must be maintained at the maximum allowable for the size of the filter and the maximum permissible filtering rates.

The supply of influent water is usually fixed by the elevation of the outlet weir from the coagulating basin where the influent flow is by gravity. If pumping is required, the level may be controlled by a floating controlled inlet valve which opens when the water level drops and closes when it rises. The discharge rate of the filter may be controlled manually by use of a butterfly or plug-type valve, or it may be controlled by an automatic rate-of-flow controller.

WASHING FILTERS

After a filter has been in service for some time, foreign matter will have collected on the surface and in the top layers of sand to the extent that the loss of head becomes excessive. It is then necessary that the filter be backwashed to clean the sand bed. It is usual practice to wash a filter when the loss-of-head has reached 7 to 9 feet, or after about 50 hours of service, whichever occurs first. (The practice is the same for both sand and anthracite filters.) The bed is washed by reversing the flow to force the filtered water up through the gravel and sand. This loosens the bed, agitates the sand grains against each other and washes accumulated foreign matter from the grain surfaces. The wash water rises into the wash troughs and flows to waste through the plant sewer, carrying the foreign matter with it. The wash water is usually discharged to a stream for disposal, but in some cases it is necessary to discharge it to a settling pond to avoid stream pollution.

Methods of Washing

Although there are some differences in the details for different rapid sand filters, the basic method of operation and washing is the same. The main differences are in operating controls and instruments and gages. In small plants having manual operation, it is necessary to operate each valve by hand and only loss-of-head gages are provided. In larger and more elaborate plants, filter operating tables are provided where the valves are operated or controlled by push buttons or small levers, and a number of additional instruments and gages are provided. Because of the variations in control of different rapid sandfilters, operators are instructed to consult the manufacturer's instructions for precise procedures in filter washing.

Wash-Water Rate

The wash-water rate should be the maximum possible without causing a loss of filter media with the wash water. In general, the wash-water rate should never be lower than 15 gpm per square foot of filter bed area. This gives a "wash-water rise" of 2 feet per minute in the filter above the sand. Higher rates, up to 4 feet per minute, may be desirable in some cases, an average rate being about 2.5 to 3 feet per minute. The most desirable rate is that which affords good cleaning of the filter with the least quantity of water and without loss of filter sand. Because of the increased specific gravity and viscosity of water at lower temperatures, higher wash-water rates are often used in cold weather in order to get effective expansion and cleaning of the sand bed. Lower wash rates are needed with anthrafilt than with sand. Usually, a wash rate one-half that for sand filters is sufficient for washing anthracite filters.

Control of Wash Rate

Wash water is supplied either by gravity from an elevated storage tank at the plant, from the water distribution system, or from a pump operating from the filtered water reservoir or the clear-well. Control of the amount of wash water is usually accomplished by a rate-of-flow controller, or a butterfly or plug-type valve located in the wash-water line. A pressure gage should be located on the operating floor to indicate the pressure in the wash-water line at the discharge end of the wash-water controller or valve. Test measurements of the expansion of the filter bed in the filter at different wash-water rates should be made and the pressure gage reading taken for each rate. Satisfactory washing occurs when the expansion is about 40 percent of the normal depth of sand (e.g., a 24-inch depth of sand should occupy a depth of 30 to 36 inches during the washing process). The operator can adjust the valve from time to time according to the pressure gage reading in order to maintain the desired rate.

Sand Expansion

The most satisfactory method of adjusting the wash-water rate so as to avoid loss of sand is by measuring the expansion of the sand bed during washing. Sand expansion may be measured by two methods. Cups are attached at 1-inch intervals along a pole and the pole lowered into the filter during washing (the highest cup which collects sand indicates the height of sand expansion). Or a hook light (see fig. 9-16) with a WATERPROOF BATTERY-OPERATED LAMP is lowered into the filter while washing until the light just disappears; this shows the height to which the sand has expanded. NEVER use a light CONNECTED to a power source.

Measuring Wash Rate

The rate of washing can be found by drawing the water down so that it is level with the top of the wash-water trough, closing the wash-water drain valve, then opening the wash-water valve to normal setting. Observe the time required (in decimal parts of a minute) for wash water to rise 12 inches in the filter. Divide 12 by this figure to find rise in inches per minute.

Washing Time

The time needed to wash the filter bed varies with the type of filter media, sand grain size, condition of water and rate of wash. Generally, a bed can be cleaned adequately in 3 to 5 minutes. However, the best evidence that the bed is cleaned is the appearance of clean wash water above the bed. The filter operator must observe the wash water closely during backwashing in order to determine when the wash is completed and to conserve wash water. The more thoroughly the bed is washed, the longer it can be used before it becomes clogged. In addition, accumulations of mud balls and cracking of the bed will be prevented.

Surface Wash

Surface washing is a method of cleaning sand to aid the conventional reverse-flow washing.

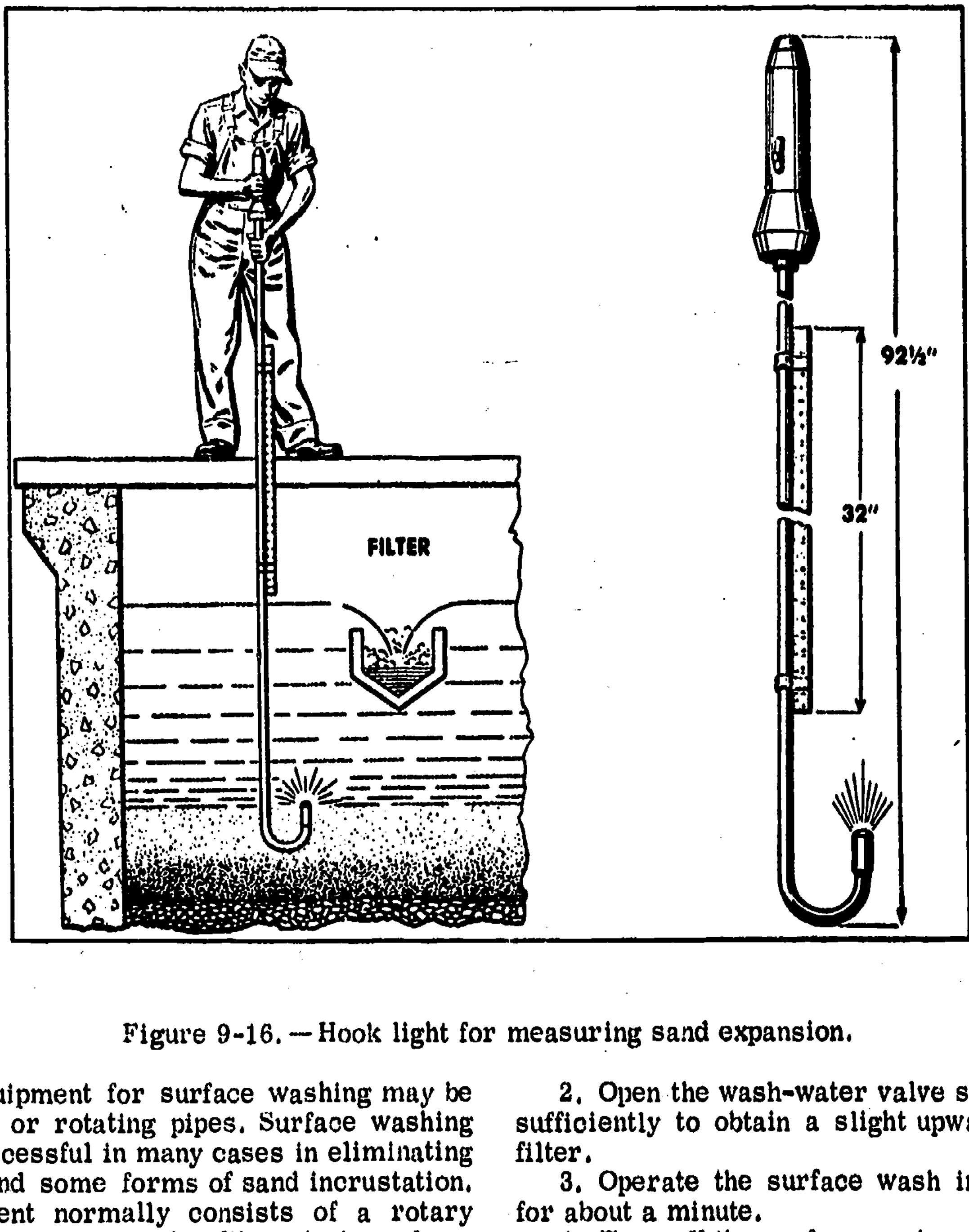

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Figure 9-16.—Hook light for measuring sand expansion.

Installed equipment for surface washing may be either fixed or rotating pipes. Surface washing has been successful in many cases in eliminating mud balls and some forms of sand incrustation. The equipment normally consists of a rotary distributor just above the filter bed surface. The nozzles point down at about a 45° angle to the sand surface (see fig. 9-8). Agitation by high pressure water jets serves to scrub the sand grains against each other and break loose any attached foreign matter. The jets also furnish the force required to rotate the pipe arms. Water is required for surface waste at 0.5 gpm per square foot of filter area at not less than 50 psi. The surface washing procedure consists of the following steps:

1. Bring the water level in the filter up to the level of the wash trough and start the surface wash.

2. Open the wash-water valve slowly and only sufficiently to obtain a slight upward flow in the filter.

3. Operate the surface wash in this manner for about a minute.

4. Turn off the surface wash.

5. Proceed with normal filter washing. Surface washing of filters may also be accomplished manually by directing a high pressure stream from a fire hose into the sand while washing the filter, or by attaching a piece of perforated pipe to a fire hose and moving the device about on the sand surface during washing.

OPERATING TROUBLES IN RAPID SAND FILTERS

Operating troubles commonly encountered in rapid sand filters include mud balls, clogging, and air-binding.

Mud Balls

If a filter bed is not backwashed correctly, sand grains and foreign matter begin to stick together. Over a period of time, large clumps, called mud balls, are formed. They lower the efficiency of the filter bed and must be removed. Surface washing usually breaks down these formations and they can then be removed by backwashing. If the plant does not have surface wash equipment, mud balls may be removed in the following manner:

1. Wash the filter bed completely clean at 2- to 3-week intervals, using about twice the usual amount of backwash to make sure the bed is cleaned thoroughly.
2. When the wash water is clear, reduce the rate until the bed is expanded about 20 to 25 percent. This exposes mud balls on the sand surface.
3. Remove the mud balls manually with a 10-mesh screen attached to a long handle.

Clogging

Normally, filter sands become clogged only at the surface and are restored to use by ordinary washing methods. Sometimes, however, the entire sand bed becomes clogged and caked and cannot filter properly. It can then be restored to use only by removal of the sand and gravel from the filter and thoroughly washing or replacing it as may be needed.

Air-Binding

Air-binding occurs when pockets of air accumulate in the sand. It interferes with proper filtration, as indicated by high loss of head.

Air binding is caused by:

1. Operating with insufficient water above the sand.
2. Permitting relatively rapid fluctuations in head, causing holes to be blown in the sand bed.
3. Filling the filter too rapidly when returning it to service after washing.
4. Allowing the water level to drop below the surface of the sand bed when draining the filter for inspection.

Air-binding can be corrected by these procedures.

1. Fill the bed slowly from the bottom through the wash-water line to force the air out of the filter. This must be done carefully to prevent violent agitation of the sand bed. Allow the bed to stand idle for several hours after filling.
2. Keep the depth of the water in the top of the filter greater than the total loss of head through the filter before it is cleaned in order to prevent development of partial vacuum and air pockets. Usually the depth of water required above the sand is about 5 feet. In most designs, this permits a 7- to 9-foot loss of head before the filter begins to operate under vacuum.
3. During operations, avoid wide fluctuations in head which may cause holes to be blown in the sand.

OPERATION OF DIATOMITE FILTERS

The diatomite filter is usually of the pressure type (see fig. 9-10). It consists of a number of cylindrical filter elements suspended from a plate within a pressure vessel.

At the start of the filtering run, the filter elements are given a thin coat of diatomaceous earth simply by introducing a slurry of the diatomaceous earth into the filter inlet and then recirculating the water for several minutes. This coating (called the pre-coat) is the filter medium which accomplishes the filtering. As in sand filters, the dirt accumulates on the filter medium; likewise, the loss of head through the medium increases. This serves as the operator's guide to the proper time to backwash the filter. The length of the filtering run may be increased by feeding small amounts of diatomite slurry (called the body coat) during the run.

Cleaning or backwashing is accomplished by surging liquid backward several times through the filter to the point of backwash discharge. A quick-opening valve is used in this operation, and only a minute or two is required to completely clean the filter.

Some types of elements, because they have a tendency to plug with the diatomite, require a backflow of compressed air for proper cleaning. Most manufacturers of wire-wound elements now recommend using an air pump to clean the elements.

Some elements made of a more flexible material, such as woven cloth, are more easily cleaned because of their ability to expand and contract with the flow of water. This is similar to the action of washing clothes in a washing machine.

CHAPTER 10

QUALITY CONTROL IN WATER TREATMENT

Frequent chemical analyses and bacteriological examinations of raw and treated water are required to determine and control treatment to ensure a safe, potable water. Chemical analyses will determine proper water treatment and the safety of the water in respect to chemical content. Bacteriological examinations will determine the necessity for disinfection as well as the safety of the water following treatment in terms of bacteria content.

As a Utilitiesman, you may be called upon to collect samples of water for chemical analysis and bacteriological examination. You may also have to make various types of treatment control tests. This chapter provides information that will aid you in performing these duties. Safety precautions to be observed by personnel engaged in laboratory work also are covered.

SAMPLING METHODS

The collection of samples for testing for quality control and safety is an important function, because, unless the water sample is representative and uncontaminated, test results will not indicate the actual condition of the water supply. Sample containers should be of materials that will not contaminate the sample and, before use, should be cleaned thoroughly with a detergent and fresh water rinse to remove all surface dirt. Chemically resistant glass is a suitable material for all sample containers, and polyethylene may be used for samples for chemical analyses. The size of the sample container used will depend upon the amount of water needed for a particular test.

To make certain that representative, uncontaminated samples are obtained, you must observe normal precautions against accidental contamination. Sample containers and caps should always be rinsed well with the water to be tested. Direct hand contact with the mouth of the container, or with the cap, is to be avoided. Take samples with a minimum of splashing.

CHEMICAL ANALYSIS SAMPLES

When collecting samples for chemical analysis, usually a gallon of water is adequate for the determination of the mineral content. In order to obtain accurate test results, sampling lines should be thoroughly flushed and the bottles rinsed out several times with the water to be collected. Procedures for obtaining samples for chemical analysis are given below. These procedures should be carefully followed.

Wells

In order to obtain a representative sample from a well, pump the well until the normal drawdown is reached. Rinse the chemically cleaned sample container and cap several times with the water to be tested and then fill with a minimum of splashing.

Surface Supplies

When sampling surface supplies, fill chemically cleaned raw-water sample containers with water from the pump discharge ONLY after the pump has operated long enough to flush the discharge line. Take the sample from the pond, the lake, or the stream at intake depth and location with a submerged sampler. Submerged samplers are equipped with automatic or manual valve systems that permit the collection of water at the desired depth.

Treatment Plants

Take samples inside a treatment plant from channels, pipe taps or other points where good mixing is obtained. At some Navy installations, special sample taps are provided for this purpose.

Taps on Distribution System

In the case of taps on a distribution system, let the tap run long enough to draw water from the main before taking samples.

BACTERIOLOGICAL EXAMINATION SAMPLES

In obtaining samples for bacteriological examination, contamination of the bottle, stopper or sample often causes a potable water supply to be reported as nonpotable. Full compliance with all precautions set forth below is necessary to ensure valid results.

Sample Containers

Use only clean sterilized bottles furnished by the medical department of the installation, or another qualified laboratory. (See fig. 10-1.) If bottles are not available from these sources, sterilization may be carried out in emergencies. The tops and necks of sample bottles with glass closures should be covered with metal foil, rubberized cloth or heavy impermeable paper or milk bottle cover caps before sterilization. Before sterilizing the sample bottle to be used for a chlorinated water sample, place 0.02 to 0.05 gram of thiosulfate, powdered or in solution, into each bottle to neutralize the chlorine residual in the sample. Keep the sterilization temperature under 393° F (200° C) to avoid decomposition of the thiosulfate.

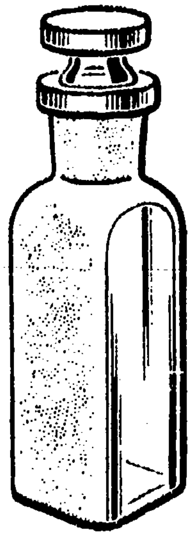

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Figure 10-1. — Bacteriological sample bottle.

Sampling From A Tap

When sampling from a tap, heat the outlet with an alcohol or gasoline torch for a few seconds to destroy any contaminating material that may be on the lip of the faucet. Occasionally, extra samples may be collected without flaming the faucet in order to determine whether certain faucet outlets are contaminated.

Flush the tap long enough to draw water from the main. NEVER use a rubber hose or another temporary attachment when drawing a sample for bacteriological examination from the tap.

Next, without removing the protective cover, remove the bottle stopper and hold both the cover and the stopper in one hand. Do not touch the bottle mouth or the sides of the stopper. Fill the bottle without rinsing (to avoid loss of thiosulfate). Replace the cap and fasten the protective covering carefully.

Sampling From Tanks, Lakes, Streams, and Pools

When collecting samples from standing water, remove the stopper as above, and plunge the bottle, mouth down, and hold at about a 45° angle at least 3 inches below the surface. Tilt the bottle and allow air to escape and fill, moving it in a direction away from the hand holding it, so that water that has touched the hand does not enter the bottle. Discard a quarter of the water and replace the stopper.

When collecting a sample from LAKES or PONDS, take the water 25 feet or more from the shore (from boat or pier) and preferably in water at least 4 feet deep. Do not collect the sample at the shore.

A STREAM sample should be collected at the point where the water is flowing, not from still areas. In a meandering stream, collect the sample at a point where flow velocity is normal. Use the procedure given above for standing water samples.

When collecting water from a swimming pool, take the water from the side of the pool nearest the deepest part. Sample the pool while it is in use, preferably during the heaviest bathing load. Use the bottle containing thiosulfate. Fill according to the sampling procedure given above for standing water.

TREATMENT CONTROL TEST PROCEDURES

Various analysis of water must be performed by trained chemists or skilled laboratory technicians. As a UT, however, you must be able to perform various types of TREATMENT CONTROL tests. These tests are used during treatment to ensure proper operation and the output of a safe water of acceptable quality. We will describe the procedure to follow in carrying out a number of treatment control tests for different major treatment processes—such as chlorination, corrosion control, and clarification.

Before proceeding, note that certain of the tests which we will cover are based on the simple principle of adding to the sample a chemical that forms a color with the substance to be measured, and matching the treated sample

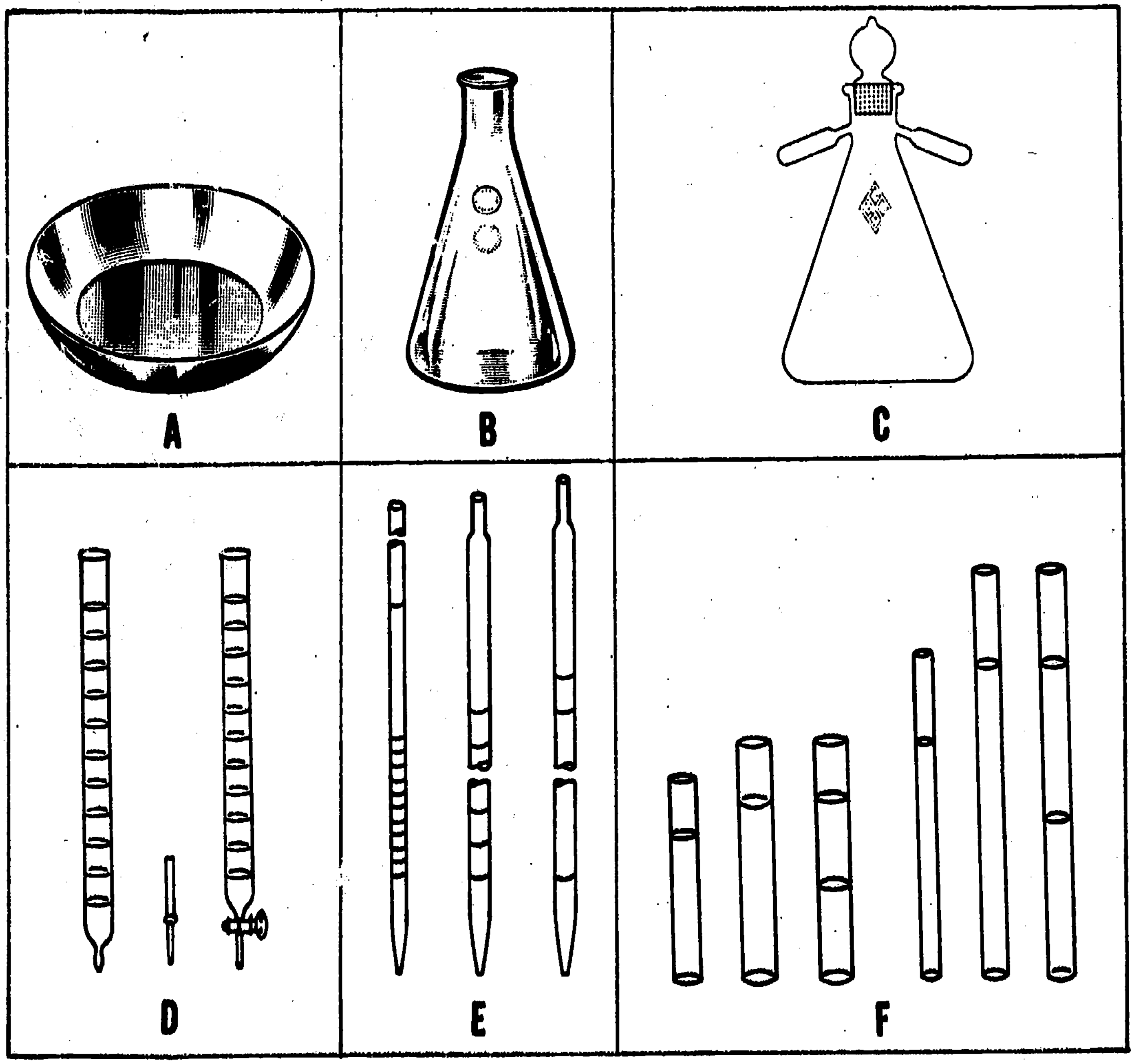

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Figure 10-2.—Common laboratory equipment. (A) Evaporating dish. (B) Erlenmeyer flask. (C) Titration flask. (D) Burettes. (E) Pipettes. (F) Nessler tubes.

with color standards containing known amounts of the substance. There are several colorimeter sets available commercially which vary slightly in use and operation. For that reason, make a careful study of the manufacturer's instructions before using such equipment. Other tests are performed by titration or by special instruments. Titration is the process of finding out how much of a substance is contained in a given solution by measuring how much of another substance or reagent has to be added to the given solution in order to produce a given reaction. Common laboratory equipment used in performing treatment control tests is illustrated in figure 10-2.

In addition, note that the various reagents required for the tests discussed below are available from a number of manufacturers and laboratory supply houses. Some of these reagents require special preparation and handling prior to test use. This is customarily the responsibility of the laboratory technician, since in some cases the preparation of reagents requires a thorough knowledge of the chemical procedures involved. For complete information on the preparation of reagents, refer to the manufacturer's instructions or consult your supervising petty officer.

CHLORINE RESIDUALS

Two tests are frequently used in testing water for chlorine residuals. They are the orthotolidine test and the orthotolidine-arsenite (OTA) test. Each of these tests is discussed separately below.

Orthotolidine Test

Chlorine residuals can be measured easily using a commercial comparator and orthotolidine reagent.

EQUIPMENT.—Either a disk or slide comparator may be used in performing the orthotolidine test. A disk comparator is illustrated in figure 10-3. This comparator consists of a standard-color disk and two sample tubes. Water to be tested is placed in both tubes. Reagent is added to one and the resulting color matched with the disk. The other tube is placed behind the disk to eliminate any color error that might be caused by turbidity in the test sample.

A slide comparator, also referred to as a block comparator, is shown in figure 10-4. This comparator consists of standard-color ampoules for more accurate color matching. The other two sample tubes are used as compensators and are placed behind the color ampoules.

REAGENT.—The only reagent used is standard orthotolidine solution.

TEST PROCEDURE.—In testing for chlorine residuals, follow specific instructions of the

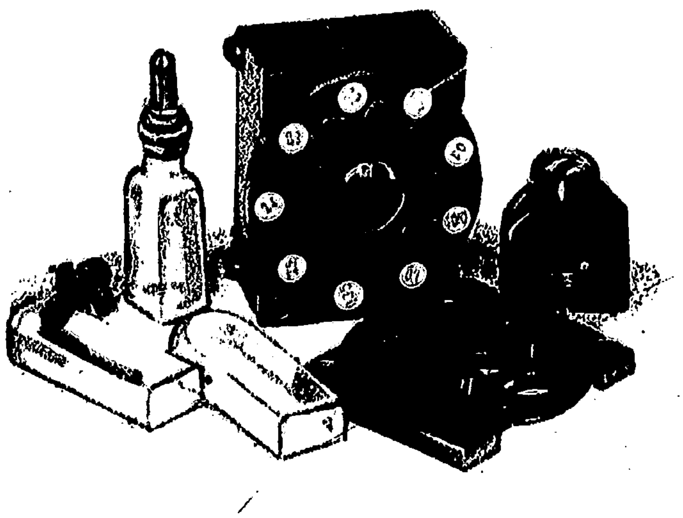

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Figure 10-3.—Disk comparator with front removed to show construction.

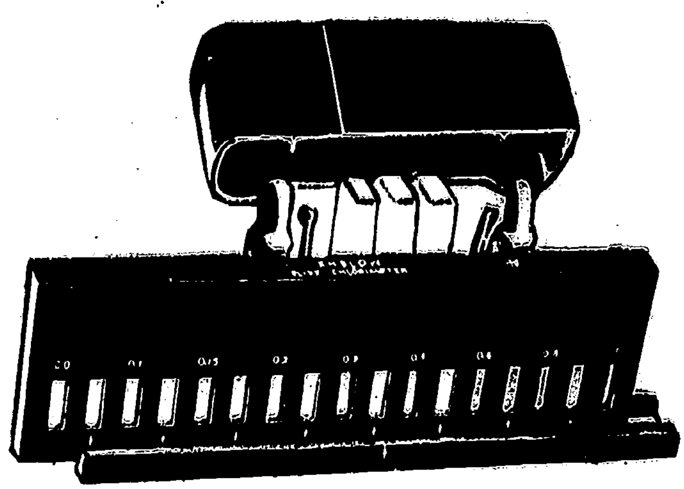

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Figure 10-4.—Slide comparator for chlorine-residual test.

manufacturer of the comparator used. The general procedure will be as follows:

1. Fill tubes to mark with water.

2. Place compensating tube or tubes behind the color standard.

3. Add 10 to 15 drops of orthotolidine to the test sample, mix, and let stand for 5 minutes. Keep the sample in the dark during 5-minute color development to reduce false color caused by manganese and nitrate compounds. If a blue color appears after 5 minutes, add more orthotolidine. If water is colder than 50° F, warm by holding tube in hand. Place sample tube in the comparator and match color, holding comparator toward the light, preferably daylight.

4. Select the standard color nearest that of the sample and read the residual. If color appears to be halfway between two standards, report residual as average of two standards. Thus, if color appears halfway between 0.3 and 0.4 ppm, report residual as 0.35 ppm.

Note that the orthotolidine test is not wholly accurate because the false color introduced by nitrates and manganese compounds cannot be entirely eliminated. However, the orthotolidine-arsenite test, described in the following section, does eliminate the false-color error completely.

Orthotolidine-Arsenite (OTA) Test

The orthotolidine-arsenite (OTA) test permits the measurement of relative amounts of total residual chlorine, free available chlorine, and combined available chlorine. This test has some limitations. In samples containing a high proportion of combined available chlorine, it may indicate more free available chlorine than is actually present, while in samples containing a low proportion of combined available chlorine, it may indicate less free available chlorine than is actually present. Precision of results depends on strict adherence to the conditions of the test. The conditions are the time intervals between addition of reagents; the relative concentration of free available chlorine, and of combined available chlorine in the sample; and the temperature of the water. The temperature of the sample under examination should never be above 68° F (20° C). The precision of the test increases with decreasing temperature.

Equipment and Reagents

You will need a color and turbidity compensating residual chlorine comparator with commercial permanent standards. The reagents used are orthotolidine (OT) and arsenite (A).

Procedures

In testing, follow the procedures outlined below.

1. Label three comparator cells A, B, and OT.

2. Use a 0.05 ml of OT reagent for each ml of the sample taken. For example, use 0.5 ml of OT reagent for a 10 ml sample and 0.75 ml for a 15 ml sample. Use the same volume of a reagent as is specified above for OT reagent.

3. To tube A, first add OT reagent, then add a measured volume of the water sample, mix quickly.

4. Within 5 seconds, add arsenite reagent; mix quickly.

5. Compare with color standards as rapidly as possible.

6. Record the result; the value obtained represents FREE AVAILABLE CHLORINE and interfering colors.

7. To tube B, first add arsenite reagent; then add a measured volume of water sample; mix quickly.

8. Immediately add OT reagent; mix quickly.

9. Compare with color standards as rapidly as possible.

10. Record the results as the B-1 value.

11. Compare with color standards again in exactly 5 minutes and record the result as the B-2 value; these values represent the INTERFERING COLORS present in the immediate reading B-1 and in the 5-minute reading B-2.

12. To tube OT, containing orthotolidine reagent, add a measured volume of water sample.

13. Mix quickly and compare with color standards in exactly 5 minutes.

14. Record the result; the value obtained represents the TOTAL RESIDUAL CHLORINE present and the total interfering colors.

CALCULATION OF RESULTS.—In calculating results of the orthotolidine-arsenite (OTA) test, follow the procedure below.

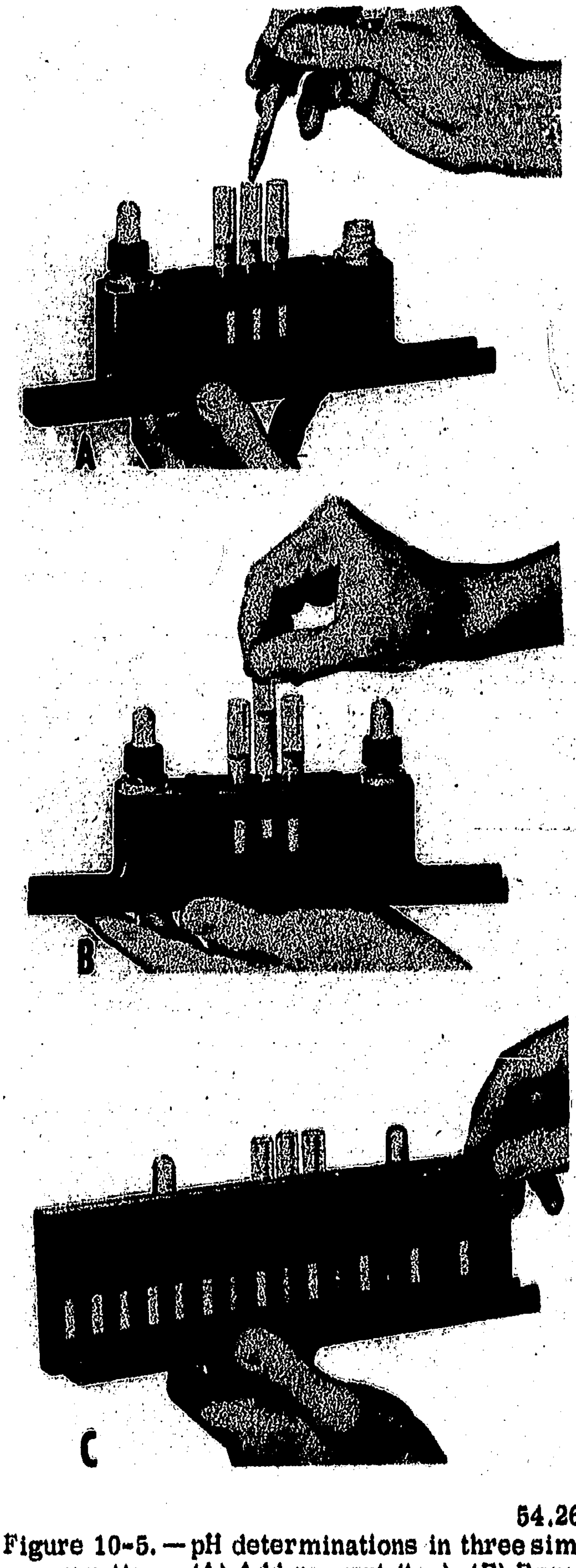

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Figure 10-5.—pH determinations in three simple operations. (A) Add reagent (top). (B) Remove tube (center). (C) Compare colors (bottom).

TOTAL RESIDUAL CHLORINE. From the value of OT subtract the value of B-2. The difference equals total residual chlorine.

(OT) - (B-2) = total residual chlorine

FREE AVAILABLE CHLORINE. From the value of A subtract the value of B-1. The difference equals free available chlorine.

(A) - (B-1) = free available chlorine

COMBINED AVAILABLE CHLORINE. From the value of total residual chlorine, subtract the value of free available chlorine. The difference represents combined available chlorine.

(Total residual chlorine) - (free available chlorine) = combined available chlorine.

TEST FOR pH

The pH test is a measure of the strength of acid or alkali in a water. It is reported on a scale of 14 units on which pH7 is neutral (in a technical sense), values below 7 are acid, and those above 7 are alkaline. Color comparators can be used to find pH by methods similar to those for determining chlorine residuals. The determination of pH in three simple operations is shown in figure 10-5.

Indicators

Many pH indicators are available, each with a limited range. The following are usually used for treated water supplies:

pH RANGE	INDICATOR
5.2 to 6.8	Chlorphenol red
6.0 to 7.6	Bromthymol blue
6.8 to 8.4	Phenol red
7.2 to 8.8	Cresol red
8.0 to 9.6	Thymol blue

The correct standards must be used with each indicator.

Procedure

In making the pH test, proceed as follows:

1. Fill the tubes to the mark with the sample.
2. Add the indicator to one tube in the amount specified by the manufacturer. (NOTE: Usually

0.5 ml (10 drops) for a 10 ml sample tube and proportionately more for larger tubes).

3. Mix and place the tube in the comparator.

4. Match for color and read the pH directly.

5. If the color matches the standard at either the upper or the lower end of the range of the indicator, repeat the test with the next higher or lower indicator. For instance, if bromthymol blue is used and the sample matches the blue color of the 7.6 standard, the pH is 7.6 or higher. Therefore, use a phenol red indicator to check this value.

SALINITY TESTS

At times you may be assigned to perform salinity tests with a field water, quality-control kit. These tests serve to identify mineral characteristics of the water.

The quality-control kit provides the necessary materials and equipment for the tests. Two bottles of reagents, one small and one large, are included. As the solution is used up during the test, the small bottle is refilled from the larger bottle. The test bottles have two marks, the lower one at 50-ml (milliliter) capacity and the upper one at 100-ml capacity. The test solutions are measured with pipettes. These pipettes deliver a total of 1-ml from the upper graduation mark and are calibrated in 1/10-ml divisions. Each pipette is to be used only for the test for which it is marked in the pipette case and is to be returned directly to its place when the test is completed.

Four types of salinity tests which you may perform are: the alkalinity test, the hardness test, the chloride test, and the sulfate test. Each of these tests is discussed separately in subsections below.

Alkalinity

Alkalinity of water results from the presence of bicarbonate, carbonate and hydroxides of calcium, magnesium, sodium and other minerals. The term "alkalinity" has little or no relation to the pH of the water. It refers to the acid neutralizing capacity of the water. In other words, alkalinity of water refers to the amount of various alkalies in the water which are capable of neutralizing acids. One method of determining the alkalinity of a water sample is by titration with standard sulfuric acid first to the phenolphthalein (PT) end point, and then to the methyl purple or methyl orange end point. Although methyl orange is the "standard indicator," methyl purple is much easier for the average operator to use because its color change is easier to see, and the results obtained with it are good enough for almost all uses.

REAGENTS.—The reagents used in testing the alkalinity of water are:

Phenolphthalein (PT) Indicator Solution.
Methyl Purple Indicator Solution.
Methyl Orange Indicator Solution.
Standard Sulfuric Acid (N/50).

PROCEDURE WITH METHYL PURPLE.—In determining the alkalinity of water with methyl purple, the following procedure applies:

1. Measure 100 ml of the clear sample (filtered if necessary) into an evaporating dish or Erlenmeyer flask (see fig. 10-2).

2. Add 4 drops of phenolphthalein indicator solution. If a pink or red color develops, phenolphthalein alkalinity (alkalinity fraction contributed by hydroxide and half of carbonate) is present.

3. Fill the burette with acid and add to the sample slowly just until the pink color disappears.

4. Record the ml of acid used.

5. Now add two to four drops of methyl purple indicator.

6. Continue titration, adding the acid in 0.5 ml portions until a greenish tint appears where the acid hits the sample. Then continue the addition more slowly, about three drops at a time. The color will change from green to gray and then to purple. The appearance of the purple tint marks the end point.

7. Record the total ml of acid required to reach this end point. This includes the ml of acid used in the phenolphthalein alkalinity titration and that used in the methyl purple titration.

PROCEDURE WITH METHYL ORANGE.—In determining the alkalinity of water with methyl orange, follow the procedure given below.

1. Measure 100 ml of the clear sample (filtered if necessary) into an evaporating dish or Erlenmeyer flask. (NOTE: If an evaporating dish is used to get a white background for better color observation, the sample must be stirred with a stirring rod during addition of the standard acid.)

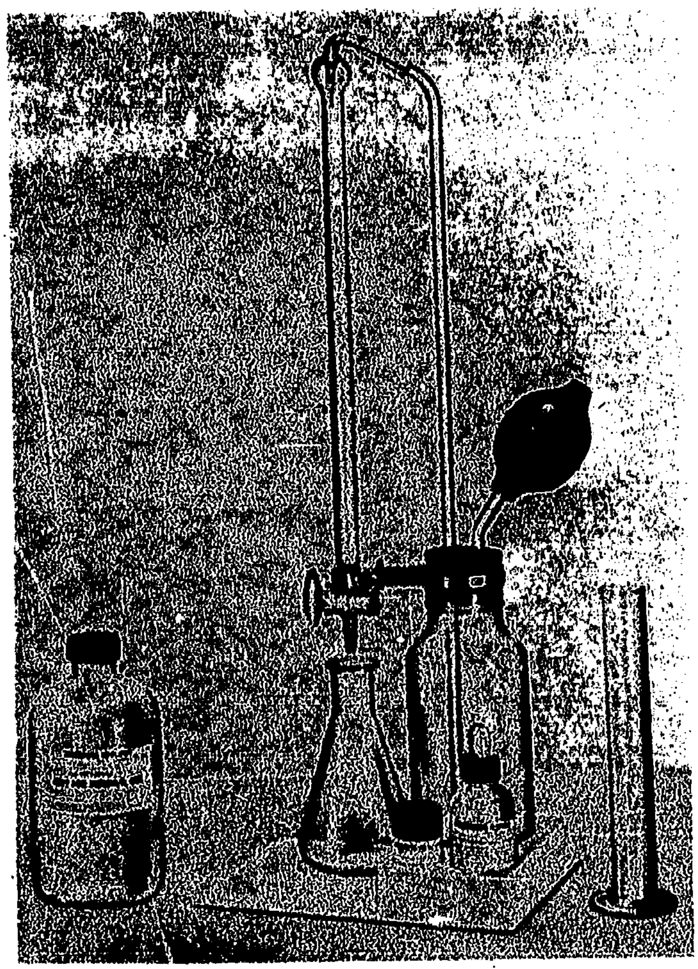

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Figure 10-6.—Total hardness test set (EDTA).

2. Add four drops of phenolphthalein indicator solution. If a pink or red color develops, phenolphthalein alkalinity (alkalinity fraction contributed by hydroxide and half of carbonate) is present.

3. Fill the burette with the acid and add to the sample slowly just until the pink color disappears.

4. Record the ml of acid used.

5. Now add two to four drops of methyl orange indicator.

6. Continue titration, adding the acid in 0.5 ml portions, until the reddish color which appears where the acid hits the sample begins to persist. Then continue the addition more slowly, about three drops at a time, until the first pinkish tinge is seen throughout the sample. This is the end point.

7. Record the total ml of acid required to reach this end point. This includes the ml consumed in the phenolphthalein alkalinity titration and that consumed in the methyl orange titration.

CALCULATIONS.—The phenolphthalein (PT) alkalinity is calculated as ppm of calcium carbonate, by multiplying the ml of acid used in the phenolphthalein titration by 20.

ppm PT alkalinity as calcium carbonate = ml of acid used in step x 20.

The total alkalinity, as ppm of calcium carbonate, is found by multiplying the total number of ml of acid used (step 6 above) by 20. This applies to both the methyl orange and the methyl purple procedures.

ppm total alkalinity as calcium carbonate = total ml acid used by 20.

Hardness

The titration method for determining water hardness is vastly superior to the old soap test which is slow, tedious, and often may give misleading results. The procedure is based on the fact that when a sample of water is titrated with a solution of EDTA (sodium ethylene, diamine tetra-acetate), calcium and magnesium react with the EDTA to form soluble compounds in which calcium and magnesium are tied up so firmly that they cannot react with other materials. Standard EDTA solution is added to a water sample and the end point is detected by an indicator which is red in the presence of calcium and magnesium ions and blue in their absence. A total hardness test set (EDTA) is shown in figure 10-6.

REAGENTS.—The following reagents are used in testing for water hardness:

EDTA solution
Hardness indicator powder
Hardness buffer
Hardness reagent.

PROCEDURE.—In determining water hardness, here is the procedure to follow.

1. Place a 50 ml sample in a 250 ml Erlenmeyer flask.
2. Add one dipper of hardness indicator powder.
3. Add 0.5 ml of hardness buffer to hold the pH at around 10. The color of the mixture will be red if any hardness is present.

4. Add the hardness reagent from a burette until the red color just disappears, giving way to a pure blue.

CALCULATIONS. — The burette reading in ml is multiplied by 20 to give the total hardness.

ppm total hardness as calcium carbonate = ml burette reading x 20.

The Chloride Test

The purpose of the chloride test is to measure the amount of chloride ions and common salt (NaCl) contained in water. This test also indicates the presence of possible sewage pollution.

REAGENTS. — The reagents used in making the chloride tests are as follows:

Phenolphthalein Indicator
Methyl Orange Indicator
Potassium Chromate
Silver Nitrate Standard
Aluminum Hydroxide
Sulfuric Acid (1 to 3)

PROCEDURE. — When making a chloride test, follow the procedure below.

1. Pipette 50 ml of the sample into a 6-inch white porcelain evaporation dish.
2. Place the same quantity of distilled water into a second dish for color comparison.
3. To both dishes add 1 ml of potassium chromate. Titrate the dish with the sample. Add standard silver nitrate solution (2.4 grams per liter) from a burette, a few drops at a time, with constant stirring until the first permanent reddish coloration appears. (This can be determined by comparison with the distilled water blank.) Record the ml of silver nitrate used.
4. If more than 7 or 8 ml of silver nitrate solution are required, the entire procedure should be repeated, using a smaller sample diluted to 50 ml with distilled water.

CALCULATIONS. — When making calculations for chloride, use the formula below.

$$\text{ppm chloride (Cl)} = \frac{(\text{ml of } AgNO_3 \text{ used} - 0.2) \times 500}{\text{ml of sample}}$$

Three precautions to bear in mind are:

1. If the sample is highly colored, it should be decolorized by shaking with washed aluminum hydroxide and filtering.

2. If the sample is highly acid, add 10% sodium carbonate solution until it is slightly alkaline to methyl orange.

3. If the sample is highly alkaline, add diluted sulfuric acid until it is just acid to phenolphthalein.

The Sulfate Test

The sulfate test is used to determine whether sulfates are present in sufficient quantities in water to cause undesirable physiological effects (sulfates can cause diarrhea in human beings).

In the sulfate test, the sulfate value is found by trial, as the test merely determines approximate values. For this reason, it may be necessary to repeat the test several times. The test is begun by testing for sulfates at 100 ppm as follows:

1. Fill a clean test bottle to the 100-ml mark with the water sample.
2. Add 1 ml of barium-chloride solution to the sample using a barium-chloride pipette. Shake intermittently for 10 minutes.
3. Tear a piece of filter paper into small pieces and place the pieces in the solution.
4. Shake the bottle for 5 minutes or until the paper becomes fluffy and gelatinous.
5. Place a funnel and filter paper in a second bottle.
6. Filter about 25 ml of the sample into the second bottle. Rinse the second bottle with this amount of filtrate, and discard the filtrate. Replace the funnel and continue filtration until 50 ml of filtrate are collected.
7. Add 1 ml of barium-chloride solution to the filtrate with the barium-chloride pipette. Shake for 5 seconds, and observe immediately for a precipitate or clear solution.

If a clear solution is obtained, record the sulfates as less than 100 ppm. As immediate precipitate or milky solution indicates the sulfates are greater than 100 ppm and a new sample must be tested for 200-ppm sulfate. For each additional 100-ppm sulfate test required, add an additional 1 ml of barium-chloride solution. Therefore, 3 ml of barium-chloride solution must be added to test for 300-ppm sulfate. However, the 1 ml of barium-chloride solution added after filtration is not changed.

If a clear solution is obtained, the sulfates are less than the ppm for which they were tested, and the value is recorded as being between the values of the last preceding tests.

A precipitate or milky solution requires that a new sample of the water be tested for the next higher value.

COLOR

Color in water is due to various materials in solution, although suspended turbidity occasionally adds an apparent color to water which may add to or disguise the true color. In water with low turbidity, the apparent color corresponds closely to the true color. However, if turbidity is high, the apparent color may be misleading. In such cases, in order to determine the true color, the water should first be filtered through clean white filter paper before comparing with the standards. Because the filter paper often removes some true color from the first portion of the sample, discard the first 100 ml which pass through the filter and use the next portion for the color comparison. Make the color determination by matching the sample color with color standards in a color comparator.

TASTE AND ODOR

Unless the water has a definite taste (sweet, sour, salty or bitter) the sensation produced upon the observer is generally due to the presence of odor rather than taste. These two senses work in unison. A sulfur water, for instance, apparently tastes "terrible" when it is really only its rotten egg odor which is registering on our senses. From the standpoint of measured observations, odor determinations are much to be preferred to taste determinations. There is no method for measuring tastes quantitatively.

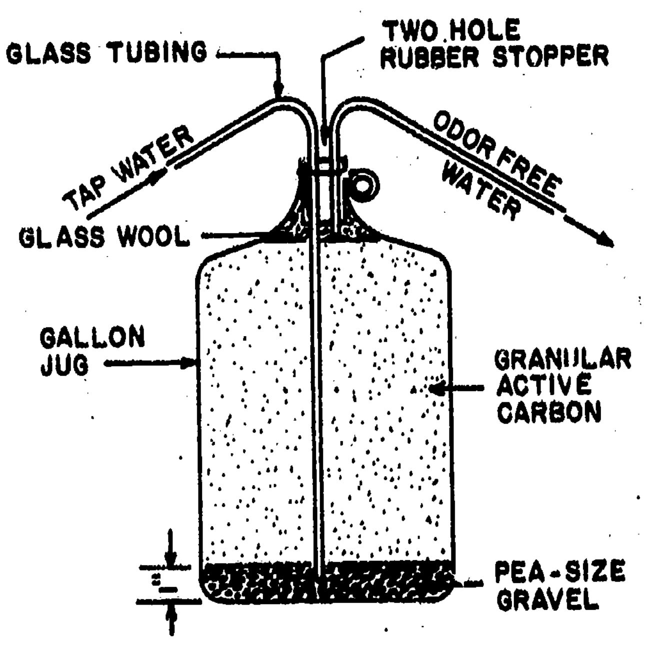

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Figure 10-7.—Odor-free water generator.

Threshold Odor Test

The threshold odor test is the most widely used method of determining odor levels. It consists of comparing different dilutions of the sample (diluted with odor-free water) to an odor-free standard. The dilution at which the odor can just be detected is called the threshold point. The odor at the threshold point is expressed quantitatively by the threshold number. This is simply the number of times the odor-bearing sample is diluted with odor-free water. For example, if an odor-bearing water requires dilution to ten times its volume with odor-free water in order to make the odor just perceptible, its threshold number will be 10. A more concentrated odor-bearing water will require dilution to 100 times its volume to make the odor just perceptible; its threshold number will be 100. Consistent measurement of odor values can be obtained only when fundamental principles are provided for. Here are some of the basic principles involved:

1. Some practice with the test is desirable to develop consistent threshold sensitivity. The consistency can be developed readily in most individuals. An accute sense of smell is by no means essential for this.

Table 10-1.—Types of Odors Commonly Encountered in Water Supplies

Aromatic (spicy)	Disagreeable
cucumber	fishy
Balsamic (flowery)	pigpen
geranium	septic (sewage)
nasturtium	Earthy
sweetish	peaty
violet	Grassy
Chemical	Musty
chlorinous	moldy
hydrocarbon (gasoline)	Vegetable
medicinal	
sulfuretted (rotten egg)	

54.327

Table 10-2.—Dilution Series for Determining the Threshold Odor Number

Series	I	II	III
Amount of sample diluted to 250 ml	250	63	16
	177	44	11
	125	31	8
	88	22	5.5
	63	16	4

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2. An adequate supply of freshly prepared odor-free water must be available before starting the test.

3. All glass must be clean and free of odor. Rinse all glassware several times with odor-free water prior to each test and between dilutions.

4. Tests should be run in a room free from foreign odors. Odors caused by fresh paint, volatile solvents, tobacco smoke, food and the like will decrease the accuracy of the observations.

5. Each dilution should be compared with the odor-less standard to check judgment and minimize reliance on odor memory.

Table 10-3.—Threshold Odor Numbers

Amount of sample diluted to 250 ml	Threshold odor number
250	1
177	1.4
125	2
88	2.8
63	4
44	5.6
31	8
22	11
16	16
11	22
8	32
5.5	45
4	64

54.329

EQUIPMENT.—The following items of equipment are needed to carry out the threshold odor test:

1. Six 500 ml Erlenmeyer flasks with ground glass stoppers.

2. Two thermometers (0° - 110° C).

3. One 250 ml graduated cylinder.

4. One 100 ml graduated cylinder.

5. One 50 ml graduated cylinder.

6. One 25 ml graduated cylinder.

7. One 10 ml Mohr pipette.

8. One large hot plate.

9. One odor-free water generator (see fig. 10-7).

10. Several large flasks for collecting and heating odor-free water.

PROCEDURE.—In carrying out the threshold test, the first step in the procedure is to

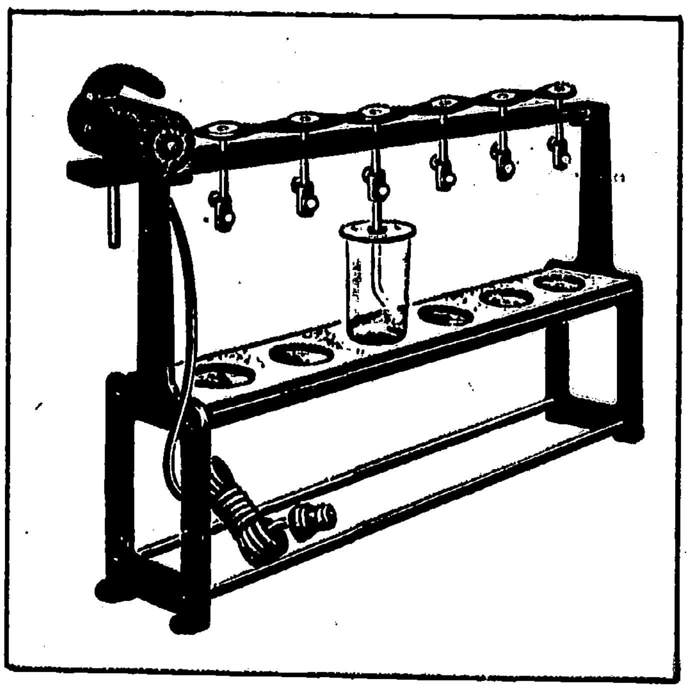

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Figure 10-8.—Variable-speed multiple stirrer.

determine the approximate range of the threshold odor number. Carefully follow the steps listed below.

1. Add 250 ml, 63 ml, 16 ml, and 4 ml portions of the odor-bearing water to separate 500 ml glass-stoppered Erlenmeyer flasks.

2. Dilute the last three to 250 ml with odor-free water.

3. Add 250 ml of odor-free water to another flask which will be the reference for comparison.

4. Heat the flasks to 140° F (60° C) on a hot plate.

5. Shake the odor-free flask, remove the stopper and sniff the vapors.

6. Do the same with the flask containing the least amount of odor-bearing water and observe by comparison whether it contains an odor, and, if so, what type odor (see table 10-1).

7. Repeat procedure in steps 5 and 6 using the sample containing the next highest concentration of the water sample.

8. Continue the process until all dilutions have been observed.

9. Record which flasks contain an odor and which do not. Experience will enable an operator to estimate the approximate odor range by sniffing the undiluted sample, thereby eliminating the preliminary test.

10. Based on the results obtained in the preliminary test, prepare a set of dilutions, using the amount of the sample diluted with odor-free water in the range corresponding to the lowest dilution in which the odor was detected. For example, if odor was detected in the 63 ml dilution, but not in the 16 ml dilution, use Series II in table 10-2.

11. Repeat the procedures in steps 5 through 9. The threshold number is read from table 10-3.

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Figure 10-9.—Jar test reagent kit.

COAGULATION TEST RESULTS

Source ______________________ By ______________________ Date ______________________

Jar No.	Temp C	Turbidity (Parts per Million)	Color (Parts per Million)	Alkalinity (Parts per Million)	pH	Dosage ppm-gpg: Alkali	Dosage ppm-gpg: Coagulant	Test Duration Minutes: Mix	Test Duration Minutes: Stir	Test Duration Minutes: Settle	Floc: Time to Appear Min.	Floc: Index	Filtrate: Color (Parts per Million)	Filtrate: Turb. (Parts per Million)	Filtrate: Residual Alumina (Parts per Million)	pH
1																
2																
3																
4																
5																
6																

Source ______________________ By ______________________ Date ______________________

1																
2																
3																
4																
5																
6																

Source ______________________ By ______________________ Date ______________________

1																
2																
3																
4																
5																
6																

FLOC INDEX FOR TESTS

0 – No Floc 2 – Smoky 4 – Pin Point 6 – Fair 8 – Good 10 – Excellent 12 – Very Heavy

54.265X

Figure 10-10. — Typical jar test data sheet.

Table 10-4.—Approximate Average Particle Size

Description	Approximate Size (Inches)
Pinpoint	Extremely fine, but visible
Fine	1/64
Small	1/32
Fair	1/32 to 3/64
Good	3/64 to 3/32
Large	1/4 and larger

54.330

JAR TEST (COAGULATION)

The jar test is a reliable method for determining the proper chemical dosages and conditions for coagulation of water to remove color and turbidity.

Equipment

For best results, a multiple stirrer with variable speed adjustment is an essential piece of equipment. It provides good control of the method of agitation and ensures that all jars will be handled in exactly the same manner.

Table 10-5. — Floc Settling Scale

Minutes to settle 4 inches	Remarks
Less than 2	Excellent: Will give excellent results in upflow solids-contact equipment at relatively high rates.
2 to 4	Good: Will give good results in upflow solids-contact equipment at moderate rates.
4 to 7	Fair: Will give satisfactory results in upflow unit if rate rise is low.
Greater than 7	Poor: Unless a low rate of rise is used, poor results will be obtained.

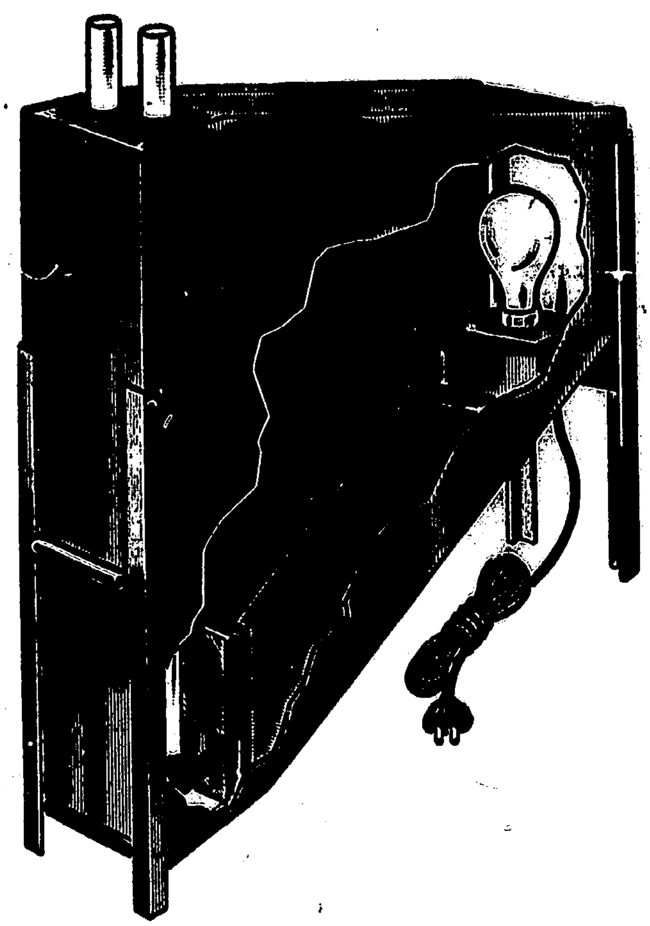
54.331

Figure 10-8 illustrates a multiple stirring apparatus that may be used. The jars are preferably illuminated from the bottom by fluorescent bulbs in a case covered with frosted glass. It has been found most convenient to run jar tests on 500 ml samples in 600 ml beakers. These work out well with the multiple stirrers, and provide sufficient depth of the sample to observe the results with ease and provide sufficient sample for analytical purposes.

Reagents

In the determination of proper coagulation, six different types of reagents may be required, depending upon what physical or chemical conditions are being tested.

1. Coagulant (alum, ferric sulfate).
2. Alkali (lime, sodium carbonate).
3. Chlorination (chlorine, chlorine dioxide).



54.266

Figure 10-11.—Turbidimeter.

4. Coagulant aid (activated silica, organic coagulant aids).
5. Weighting agent (clay, calcite flour).
6. Absorbent (powdered activated carbon).

A supply of each type of reagent should be available to run these tests. One such kit is shown in figure 10-9.

Procedure

Before starting a series of jar tests, determine the purpose of the tests, then plan conditions so that only the factor being studied is varied. For example, if it is desired to determine the effect of pH on the floc characteristics, a series of four or five samples should be run in which the coagulant dosage is constant but the alkali dosage is varied, so that each sample has a different pH. The order of the addition of chemicals, flash mix and slow mix periods, temperature of the sample and all other variables should be the same in all samples. Only the alkali dosage would vary.

FIRST SERIES.—When the primary object of the jar test is to determine the most suitable coagulant, then it is necessary to run at least one series, and usually several series, with each coagulant or combination of coagulants. The first series generally involves the addition of a fixed dosage of the coagulant (in most cases this would be alum) and a variable dosage of lime, soda ash, or sodium hydroxide in each of the jars.

SECOND SERIES.—Depending upon the results obtained in the first series, a second series will usually run over a narrower pH range using smaller differences among the jars for alkali dosages, but otherwise keeping the coagulant and its dosage the same as in the first series. Sometimes at the end of the second series, the optimum pH range is definitely established, but in other cases, it may be necessary to run additional series in order to clearly define the optimum pH band for that coagulant at the dosage level.

DETAILED PROCEDURE.—It is important to have the object of a particular series in mind at the start of the tests and to set down test conditions on data sheets, so that the object of the test will be realized at the end of the series. A typical jar test data sheet is shown in figure 10-10.

Pour the required amount of reagent into a given volume of water. (NOTE: Usually 8.1 grams of the reagent to one quart of water.) Most jar test reagent kits are supplied in vials containing 8.1 grams of the reagent.

During the addition of the chemicals, stir vigorously in order to affect quick and thorough mixing (60 to 80 rpm on a mechanical stirrer). Too rapid addition of the chemicals should be avoided and approximately the same rate of addition should be used in all samples. Note that this flash-mix period should not be less than 30 seconds, and may usually be as long as 3 to 4 minutes. Note further that if the water is warm and the floc forms quickly, there is some danger that a long flash-mix period will cause the floc which forms to break up. Under such conditions, it is better to run fewer samples or to get help in adding the treatment chemicals so that the flash-mix period can be shortened.

Slow-mix the sample for 15 to 20 minutes to keep the floc particles in intimate contact with the water and circulating continuously. If the stirring is too vigorous, the floc may break up and the results may be poor. If too little stirring is used, the clarification and color reduction may not be as complete as possible under the conditions of the test as the growing floc is not brought into contact with the impurities it is to remove.

Throughout the slow-mixing period, observe the samples carefully and record observations such as rate of formation of floc, floc size and appearance of the water between the floc particles (clear, hazy, clear but colored). The size of the floc may be described according to table 10-4.

Bear in mind that the dimensions given in table 10-4 are only a very rough scale for evaluating a floc. The size of the floc is but one criterion of the effectiveness of a set of treatment conditions. The rate of floc settling is a more important criterion and quality of the supernatant water after settling is equally important.

At the end of the slow-mix period, stop stirring and allow the floc to settle. Observe the settling carefully, reporting inches of clear water above the floc at 2 minute intervals, or more frequently, if the floc settles rapidly. Continue until all the floc is on the bottom of the jar, or for 15 minutes, whichever is shorter.

The scale in table 10-5 may be used as a rough standard for evaluating the settling rates of floc for jar tests. It is based on the period required for the floc to settle 4 inches, which is the approximate depth of a 500 ml sample in a 600 ml beaker.

POTABLE WATER SUPPLY AND DISTRIBUTION OPERATING RECORD
(See Instructions on Reverse Side)

NAVDOCKS 2568 (4-59)

ACTIVITY POST WATER WORKS, QUANTIC

DATE	WATER SUPPLIED 1000 Gallons: PURCHASED (1)	WELLS (2)	SURFACE (3)	TEMPERATURE °F (4)	pH (5)	CHLORINE RESIDUAL: CHLORINE RESIDUAL (6)	SAMPLE POINT (7)	CHLORINE RESIDUAL (8)	SAMPLE POINT (9)	CHLORINE RESIDUAL (10)	SAMPLE POINT (11)	CHLORINE RESIDUAL (12)	SAMPLE POINT (13)	CHLORINE RESIDUAL (14)	SAMPLE POINT (15)	CHLORINE Pounds: CHLORINE GAS (16)	HYPO-CHLORITE (17)	CHEMICAL INHIBITORS - Pounds: ALUM (18)	LIME (19)	PHOSPHATE (20)	(21)	(22)	FLUORIDATION: FLUORIDE POUNDS (23)
1			3733	65	7.0							1.5	3252	2.0	1303	270		1100	1000	75			100
2			3578	65	7.0							1.0+	3252	2.0	1303	252		1000	900	75			
3			3890	65	7.0							1.0+	3252	2.0	1303	238		1100	950	75			100
4			3831	65	7.0									2.0	1303	253		1100	900	75			
5			3381	65	7.0	1.5	304	0.8	2100	1.0+	2037	1.0+	3252	2.0	1303	242		1000	900	75			100
6			3439	65	7.0									2.0	1303	263		900	900	75			
7			3680	65	7.0									2.0	1303	218		1000	850	75			
8			3455	65	7.0	0.6	71					1.5	3252	2.0	1303	241		1100	950	75			100
9			3697	66	7.0							1.5	3252	2.0	1303	249		900	800	75			100
10			3418	66	7.0							1.5	3252	2.0	1303	214		900	750	75			
11			3689	66	7.0									2.0	1303	198		800	750	75			100
12			3704	66	7.0							0.8	71	2.0	1303	212		900	600	75			
13			4039	66	7.0									2.0	1303	212		1000	650	75			
14			3198	66	7.0									2.0	1303	190		800	650	75			100
15			3344	66	7.0							0.8	71	2.0	1303	241		900	650	75			
16			3420	70	7.0									2.0	1303	205		900	750	75			100
17			3423	73	7.0	0.8	71	1.0+	2037	0.6	2200	1.0+	3252	2.0	1303	225		900	700	75			
18			3844	77	7.0							.75	304	2.0	1303	240		1000	800	75			100
19			3800	77	7.0									2.0	1303	266		1100	750	75			
20			3955	77	7.0									2.0	1303	185		1000	900	75			100.
21			3063	77	7.0									2.0	1303	298		900	750	75			
22			3411	77	7.0							0.6+	71	2.0	1303	264		1000	900	75			100
23			3418	76	7.0							1.0+	3252	2.0	1303	206		800	700	75			100
24			3128	76	7.0							1.0+	3252	2.0	1303	196		700	550	75			
25			3662	76	7.0	0.8	71	1.0+	304	0.6+	2200	1.0+	2008	2.0	1303	237		800	650	75			100
26			3154	76	7.0									2.0	1303	197		700	500	100			
27			3929	76	7.0									2.0	1303	213		1100	600	100			100
28			3584	76	7.0									2.0	1303	232		900	800	100			
29			3286	68	7.0							1.4	3252	2.0	1303	278		1000	1100	100			100
30			3789	70	7.0							0.8	71	2.0	1303	268		900	1000	100			
31			3746	70	7.0							0.8	71	2.0	1303	320		900	1050	100			100
TOT.			110,688			1.5	MAX.	1.0+		1.0+		1.5		2.0									
MAX.			4039	77	7.0	0.6	MIN.	0.8		0.6		0.6+		2.0									
MIN.			3063	65	7.0							TOTAL CHEMICALS USED				7,323		29,100	24,700	2475			1600
AVE.			3570	71								TOTAL CHEMICALS ON HAND											

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ACTIVITY	MONTH AND YEAR	SOURCE OF SUPPLY
POST WATER WORKS. MAINT. DEPT. M.C.S. QUANTICO, VA.	JULY 1963	CHOPAWAMSIC CREEK

CHEMICAL INHIBITORS - Pounds					FLUORIDATION		BACTERIOLOGICAL EXAMINATION					WELL PUMPING RECORD					REMARKS
							WATER SUPPLIED		WATER DISTRIBUTED								
ALUM (18)	LIME (19)	PHOSPHATE (20)	(21)	(22)	FLUORIDE POUNDS (23)	CONCENTRATION (24)	AGAR COUNT (25)	10 ml/100 ml (26)	AGAR COUNT (27)	10 ml/100 ml (28)	SAMPLE POINT (29)	WELL NO. (30)	STATIC LEVEL (31)	DRAWDOWN (32)	HOURS PUMPED (33)	WATER PUMPED (34)	(35)
1100	1000	75			100	.98			3	Neg	2200						
1000	900	75				.98											
1100	950	75			100	.98											
1100	900	75															
1000	900	75			100	.97											
900	900	75															
1000	850	75															
1100	950	75			100	.98			0	Neg.	2200						
900	800	75			100	.95											
900	750	75				.94											
800	750	75			100	.98											
900	600	75				.97											
1000	650	75															
800	650	75			100												
900	650	75				.98			0	Neg	2200						
900	750	75			100	1.02											
900	700	75				.98											
1000	800	75			100	1.0											
1100	750	75				.99											
1000	900	75			100												
900	750	75															
1000	900	75			100	1.0			0	Neg	2200						
800	700	75			100	.98											
700	550	75				.98											
800	650	75			100	.98											
700	500	100				.98											
1100	600	100			100												
900	800	100															
1000	1100	100			100	1.02											
900	1000	100				.98											
900	1050	100			100	.98											
29,100	24,700	2475			1600										TOTAL		

Signatures

PREPARED BY: Jack Smith UT3

REVIEWED BY: Thomas Logan UTC

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Figure 10-12. — Potable Water Supply and Distribution Operating Record, NAVDOCKS 2568.

POTABLE WATER TREATMENT PLANT OPERATING RECORD *(See Instructions on Reverse Side)*

NAVDOCKS 2567 (4-59)

ACTIVITY

NAVE

DATE (0)	RAW WATER (1)	TEMPERATURE °F (2)	pH (3)	TURBIDITY (4)	COLOR (5)	CO_2 (6)	ALKALINITY P (7)	ALKALINITY M (8)	HARDNESS (9)	TDS (10)	FE (11)	Well # (12)	CHLORINE RESIDUAL (13)	WATER BY-PASSED (14)	WATER SOFTENED (15)	WASTE SLUDGE (16)	TURBIDITY (INFLUENT) (17)	(18)	HRS. FILTERS OPERATED (19)	NO. FILTERS BACKWASHED (20)	AVE. LOSS OF HEAD (21)	BACKWASH WATER (22)	Filter influent FE (23)	Filter influent hardness (24)	FILTERED WATER (25)	COLOR (26)	ODOR (27)
1	541	63	5.9	.4	NA	94	0	36	30	108	15	4	0	183	318	4	.1		168	6	NA	36	.5	65	505	NA	NA
2	539	64	5.9	.4	NA	92	0	32	30	108	18	4	0	184	315	4	.2		168	6	NA	36	.6	64	503	NA	NA
3	551	64	5.9	.5	NA	94	0	34	26	108	18	4	0	187	324	4	.1		168	6	NA	36	.9	64	515	NA	NA
4	514	63	6.3	.2	NA	113	0	56	36	140	26	3	0	165	309	4	.1		168	6	NA	36	.8	74	478	NA	NA
5	440	62	6.1	.2	NA	112	0	52	38	135	25	3	0	140	264	0	.1		168	6	NA	36	.6	76	404	NA	NA
6	531	61	6.1	.2	NA	114	0	50	40	135	25	3	0	150	337	8	.1		168	6	NA	36	.8	76	495	NA	NA
7	548	62	6.1	.2	NA	112	0	52	42	135	25	3	0	142	366	4	.2		168	6	NA	36	.5	84	512	NA	NA
8	570	62	6.1	.2	NA	112	0	50	38	135	25	3	0	156	374	4	.1		168	6	NA	36	.7	86	534	NA	NA
9	553	63	6.1	.3	NA	112	0	52	40	135	25	3	0	149	364	4	.1		168	6	NA	36	.6	86	517	NA	NA
10	550	64	6.1	.3	NA	115	0	54	36	135	24	3	0	133	377	4	.1		168	6	NA	36	.6	94	514	NA	NA
11	503	63	6.1	.2	NA	112	0	58	32	140	24	3	0	17	442	8	.2		168	6	NA	36	.5	92	467	NA	NA
12	524	64	6.1	.5	NA	114	0	54	34	135	24	3	0	125	363	0	.1		168	6	NA	36	.6	84	488	NA	NA
13	531	62	6.1	.2	NA	114	0	54	30	131	24	3	0	147	340	8	.3		168	6	NA	36	.7	94	495	NA	NA
14	574	63	6.1	.3	NA	116	0	54	36	131	24	3	0	175	359	4	.1		168	6	NA	36	.6	92	538	NA	NA
15	606	63	6.1	.3	NA	112	0	[illegible]	44	135	25	3	0	166	400	4	.2		168	6	NA	36	.6	86	570	NA	NA
16	550	63	6.1	.3	NA	114	0	52	42	144	25	3	0	152	358	4	.2		168	6	NA	36	.8	76	514	NA	NA
17	580	63	6.1	.5	NA	114	0	48	42	144	25	3	0	100	440	4	.2		168	6	NA	36	.6	80	544	NA	NA
18	544	64	6.1	.5	NA	94	0	34	36	117	15	4	0	122	378	8	.2		168	6	NA	36	.7	70	508	NA	NA
19	512	63	6.1	.5	NA	94	0	36	36	108	15	4	0	135	341	0	.1		168	6	NA	36	.5	64	476	NA	NA
20	584	62	5.9	.1	NA	92	0	34	22	108	15	4	0	174	371	8	.2		168	6	NA	36	.7	62	553	NA	NA
21	574	62	5.9	.1	NA	92	0	34	22	108	15	4	0	150	384	4	.1		168	6	NA	36	.9	68	538	NA	NA
22	563	64	5.9	.2	NA	92	0	34	22	108	15	4	0	172	351	4	.2		168	6	NA	36	.8	68	527	NA	NA
23	522	63	5.9	.2	NA	92	0	34	22	113	15	4	0	147	335	4	.2		168	6	NA	36	.8	66	486	NA	NA
24	526	62	5.9	.9	NA	92	0	34	22	108	15	4	0	151	335	4	.2		168	6	NA	36	.8	62	490	NA	NA
25	508	63	5.8	.9	NA	92	0	34	22	108	15	4	0	154	314	4	.1		168	6	NA	36	.7	62	472	NA	NA
26	516	63	5.9	.4	NA	92	0	32	24	102	15	4	0	174	302	4	.1		168	6	NA	36	.6	64	480	NA	NA
27	527	63	5.9	.6	NA	92	0	32	24	108	18	4	0	163	328	0	.1		168	6	NA	36	.6	64	491	NA	NA
28	522	62	5.7	.2	NA	92	0	34	24	108	16	4	0	148	330	8	.1		168	6	NA	36	.3	64	486	NA	NA
29	517	63	5.9	.1	NA	92	0	32	24	108	16	4	0	152	329	0	.1		168	6	NA	36	.4	64	481	NA	NA
30	574	63	5.9	.2	NA	92	0	36	28	108	15	4	0	211	339	8	.1		168	6	NA	36	.4	64	558	NA	NA
31																											
TOTAL	16219													4524	10487	128			5040	180		1080	–	–	15139		
MIN.	503	61	5.9	.1	NA	92	0	32	22	102	15	–	0	17	264	0	.3					36	.3	62	404	NA	NA
MAX.	606	64	6.3	.9	NA	115	0	54	44	144	25	–	0	211	442	8	.1					36	.9	94	570	NA	NA
AVG.	541	63	6.0	.4	NA	103	0	42	31	121	20	–	0	151	350	4	.2		168		NA	36	.6	74	505	NA	NA

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NAVENGRXSTA, Annapolis, Md.

MONTH AND YEAR November 1962

SOURCE OF SUPPLY Wells

[illegible] WATER	FINISHED WATER													CHLORINATION		FLUORIDATION		CHEMICALS USED IN POUNDS							Distribution chlorine resid. points.				
	COLOR	ODOR	TASTE	pH	TURBIDITY	CO_2	ALKALINITY P	ALKALINITY M	HARDNESS	TDS	TEMPERATURE °F			CHLORINE RESIDUAL	FEEDER SETTING	FLUORIDE CONCENTRATION	FEEDER SETTING	ALUM		PRE-LIME	POST-LIME	Clay	Rock salt		#1	#2	#3	#4	#5
(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)					
505	NA	NA	NA	8.6	.1	0	6	42	26	126	64	0		.5	5	NA	NA	NA		NA	130	180	450		.5	.5	.15	.2	
503	NA	NA	NA	8.4	.1	0	6	38	26	122	64	0		.5	5	NA	NA	NA		NA	120	150	450		.5	.5	.15	.15	
515	NA	NA	NA	8.8	.3	0	6	40	26	124	64	0		.5	4	NA	NA	NA		NA	140	170	450		.5	.5	.15	.15	
578	NA	NA	NA	9.0	.2	0	8	48	26	144	63	0		.5	4	NA	NA	NA		NA	180	220	450		.5	.2	.15	.1	
504	NA	NA	NA	8.9	.2	0	8	50	26	144	63	0		.5	4	NA	NA	NA		NA	190	200	0		.5	.35	.2	.15	
595	NA	NA	NA	9.0	.3	0	8	52	28	144	62	0		.5	5	NA	NA	NA		NA	190	215	900		.5	.35	.2	.35	
512	NA	NA	NA	8.8	.1	0	6	56	26	144	63	0		.5	5	NA	NA	NA		NA	180	220	450		.5	.35	.2	.35	
534	NA	NA	NA	8.6	.2	0	6	58	28	144	63	0		.5	5	NA	NA	NA		NA	170	200	450		.5	.35	.35	.5	
517	NA	NA	NA	8.6	.2	0	6	60	28	144	64	0		.5	5	NA	NA	NA		NA	210	200	450		.5	.5	.15	.1	
514	NA	NA	NA	8.8	.1	0	6	60	26	144	65	0		.5	4	NA	NA	NA		NA	190	210	450		.5	.15	.1	.5	
567	NA	NA	NA	8.6	.1	0	6	60	26	153	63	0		.5	4	NA	NA	NA		NA	180	200	900		.5	.15	.1	.5	
588	NA	NA	NA	9.0	.2	0	8	60	26	144	64	0		.5	4	NA	NA	NA		NA	170	180	0		.5	.15	.1	.3	
595	NA	NA	NA	9.0	.1	0	6	60	26	153	63	0		.5	NA	NA	NA	NA		NA	180	200	900		.5	.2	.1	.2	
538	NA	NA	NA	8.8	.1	0	8	60	26	144	63	0		.5	NA	NA	NA	NA		NA	170	200	450		.5	.35	.35	.35	
570	NA	NA	NA	8.6	.1	0	4	60	28	153	63	0		.5	NA	NA	NA	NA		NA	180	200	450		.5	.2	.1	.35	
514	NA	NA	NA	8.6	.1	0	6	60	28	162	64	0		.5	NA	NA	NA	NA		NA	160	190	450		.5	.2	.2	.35	
544	NA	NA	NA	8.6	.1	0	6	60	26	162	64	0		.5	NA	NA	NA	NA		NA	150	190	450		.5	.2	.1	.35	
508	NA	NA	NA	8.6	.1	0	4	50	26	144	64	0		.5	NA	NA	NA	NA		NA	130	140	900		.5	.35	.1	.35	
576	NA	NA	NA	8.6	.1	0	6	50	26	126	64	0		.5	NA	NA	NA	NA		NA	120	130	0		.5	.2	.1	.35	
553	NA	NA	NA	8.6	.1	0	6	48	26	135	64	0		.5	NA	NA	NA	NA		NA	130	140	900		.5	.15	.15	.35	
538	NA	NA	NA	8.8	.1	0	6	44	26	126	63	0		.5	NA	NA	NA	NA		NA	150	170	450		.5	.35	.2	.35	
527	NA	NA	NA	8.8	.1	0	6	44	26	126	64	0		.5	NA	NA	NA	NA		NA	120	130	450		.5	.35	.15	.35	
586	NA	NA	NA	8.9	.3	0	6	46	26	140	63	0		.5	NA	NA	NA	NA		NA	120	140	450		.5	.15	.15	.35	
590	NA	NA	NA	8.9	.1	0	8	46	26	126	62	0		.5	NA	NA	NA	NA		NA	130	140	450		.5	.35	.15	.5	
572	NA	NA	NA	8.8	.1	0	6	44	26	126	64	0		.5	NA	NA	NA	NA		NA	120	130	450		.5	.35	.1	.2	
580	NA	NA	NA	8.6	.1	0	6	44	26	126	64	0		.5	NA	NA	NA	NA		NA	120	130	450		.5	.35	.1	.1	
591	NA	NA	NA	8.6	.1	0	4	46	26	126	64	0		.5	NA	NA	NA	NA		NA	120	110	0		.5	.35	.2	.2	
586	NA	NA	NA	8.6	.1	0	6	48	26	126	64	0		.5	NA	NA	NA	NA		NA	120	130	900		.5	.35	.2	.1	
581	NA	NA	NA	8.8	.1	0	6	50	26	126	64	0		.5	NA	NA	NA	NA		NA	130	130	0		.5	.5	.2	.2	
558	NA	NA	NA	8.8	.1	0	6	46	26	126	64	0		.5	NA	NA	NA	NA		NA	140	140	900		.5	.35	.35	.5	
139														TOTAL CHEMICALS USED				NA		NA	4540	5085	4,400						
404	NA	NA	NA	8.4	.1	0	4	38	26	126	62	0		TOTAL CHEMICALS ON HAND				NA											
570	NA	NA	NA	9.0	.3	0	8	60	28	162	65	0																	
505	NA	NA	NA	8.7	.2	0	6	51	26	138	63	0																	

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Figure 10-13. —

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TYPE OF TREATMENT Degasifiers, contact precipitation (lime & clay), pressure filters and softeners and chlorination.

CALS USED IN POUNDS									BACTERIOLOGICAL EXAMINATION						
Rock salt		Distribution chlorine resid. points.					CHLORINE	FLUORIDE	RAW WATER				FINISHED WATER		REMARKS
		#1	#2	#3	#4	#5			AGAR COUNT	10/100 ml	1 ml	0.1 ml	AGAR COUNT	10/100 ml	
(48)	(49)						(55)	(56)	(57)	(58)	(59)	(60)	(61)	(62)	(63)
450		.5	.5	.15	.2		3	NA							
450		.5	.5	.15	.15		3	NA							
450		.5	.5	.15	.15		3	NA							
450		.5	.2	.15	.1		2	NA							
0		.5	.35	.2	.15		3	NA							
900		.5	.35	.2	.35		3	NA							
450		.5	.35	.2	.35		3	NA							
450		.5	.35	.35	.5		3	NA							
450		.5	.5	.15	.1		3	NA							
450		.5	.15	.1	.5		2	NA							
900		.5	.15	.1	.5		3	NA							
0		.5	.15	.1	.3		2	NA							
900		.5	.2	.1	.2		3	NA							.#1 Chlorine machine on 11/13/62.
450		.5	.35	.35	.35		2	NA							
450		.5	.2	.1	.35		3	NA							
450		.5	.2	.2	.35		3	NA							
450		.5	.2	.1	.35		3	NA							
900		.5	.35	.1	.35		3	NA							
0		.5	.2	.1	.35		2	NA							
900		.5	.15	.15	.35		2	NA							
450		.5	.35	.2	.35		2	NA							
450		.5	.35	.15	.35		2	NA							
450		.5	.15	.15	.35		2	NA							
450		.5	.35	.15	.5		2	NA							
450		.5	.35	.1	.2		2	NA							
450		.5	.35	.1	.1		2	NA							
0		.5	.35	.2	.2		3	NA							
900		.5	.35	.2	.1		2	NA							
0		.5	.5	.2	.2		2	NA							
900		.5	.35	.35	.5		2	NA							
14,400		X	X	X	X		75	NA							

Water samples from all points of distribution system analyzed by U.S.N.A. Medical Dept. and found negative during period.

SIGNATURES

PREPARED BY R.S. Johnson UT3

REVIEWED BY R.M. Davis UTC

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Figure 10-13. — Potable Water Treatment Plant Operating Record, NAVDOCKS 2567.

TURBIDITY

Special instruments are available for measuring turbidity (see fig. 10-11). These instruments greatly simplify the work of the operator performing a turbidity test. Results are reliable and accurate. Complete instructions are available from manufacturers of these instruments. In general, however, the principles of operation are the same. Usually an easy, five-step procedure, which is given below, is followed.

1. The sample tube is filled with the water to be tested.
2. The glass plunger is inserted in the tube.
3. The tube is placed in the instrument.
4. The dial at the side of the instrument is turned until the field seen in the eyepiece becomes uniform.
5. The value indicated on the dial is read and the turbidity content of the sample being tested is determined directly from a chart furnished with the instrument.

RECORDS

Results of all determinations made in the laboratory should be recorded on laboratory data forms. Two forms used for recording data are: NAVDOCKS Form 2568, Potable Water Supply and Distribution Operating Record and NAVDOCKS Form 2567, Potable Water Treatment Plant Operating Record.

NAVDOCKS Form 2568, shown in figure 10-12, is designed for use as a management tool for analysis of operating data and evaluation of potable water supply and distribution performance. Complete instructions on the method of daily entries on this form are found on its reverse side.

NAVDOCKS Form 2567, shown in figure 10-13, is designed for use as a management tool for the analysis of operating data and the evaluation of potable water treatment plant performance. A separate form should be prepared for each potable water treatment plant at an activity. Complete instructions on the method of daily entries on this form are found on its reverse side.

Both of the records above should be prepared in duplicate, and both should be summarized at the end of the month. The original should be retained on file, and the carbon copy should be forwarded to the District Public Works Officer not later than the tenth of the following month. Activity files should include records of the current and two preceding years.

Keep forms clean, concise, and hand-print with pencil or pen so as not to smear. Information on forms must be understandable and legible for future reference. Constant reference is made to the data as a means of checking and increasing plant efficiency. It provides a control measure to obtain the maximum efficiency of operation and to SAVE, not WASTE, chemicals used in water treatment.

SAFETY IN THE LABORATORY

Safety is very important in laboratory work. Some of the safety practices to be carefully observed in the laboratory are given below.

Laboratory cleanliness is extremely important for good laborary results and to maintain satisfactory plant control. Chemical tests and bacteriological examinations of water can easily be contaminated as the result of impurities introduced into the test by dirty hands, clothing, equipment, and so on. When working in the laboratory, make sure you wear clean clothing. You should also make it a practice to wash your hands thoroughly before entering and upon leaving the laboratory. In addition, set a daily schedule for cleaning the laboratory.

Hands should be kept away from the mouth and eyes when working with poisonous chemicals or bacteriological cultures. Also, any unhealed cuts on the hands or arms should be protected with sterile rubber gloves or not handled until wounds are healed. Always keep a bottle of diluted solution of lysol or other approved disinfectant at the laboratory sink. Always rinse hands with the disinfectant immediately after running tests and also after washing any bacteriological-culture glassware.

Never smoke or eat in the laboratory. Drinking from laboratory glassware may result in serious illness if a contaminated beaker is used. Do not use laboratory equipment for preparing or serving food. And, do not store food in any of the various pieces of equipment, such as the refrigerator.

Provide an assigned place for each piece of apparatus. After the apparatus is used, it should be cleaned immediately and stored in the assigned place.

Handle all equipment carefully to reduce breakage. Equipment is expensive and often difficult to obtain.

A must in all laboratories is to label all solution bottles immediately after preparation. Apply a coat of clear lacquer or shellac, to protect the label and inscription from being defaced. This procedure will eliminate serious accidents and loss of time through error.

Some organic reagents are unstable when exposed to atmosphere, light, and temperature. Reagents affected by light should be kept in amber bottles and stored in cabinets. Reagents affected by temperature should be kept in a refrigerator at 40° F. For example, the pH indicator solutions are affected by light and temperature. Bottles containing reagents affected by the atmosphere should be stoppered immediately after use, to avoid contamination by the atmosphere. This procedure applies to all chemicals used in any laboratory, as a general policy. Therefore, you must know which reagents fall in this category, and must order only in small quantities and at frequent intervals.

Wear protective clothes, glasses or face shields, when operations require.

Provide a well-stocked first aid kit in an easily accessible location.

Do not neglect any accident, no matter how insignificant. Apply first aid and notify the person in charge.

Be familiar with the type of fire extinguisher to use for each kind of fire. (Information on fire extinguishers is given in chapter 17 of this training manual.)

CHAPTER 11

MAINTENANCE OF WATER TREATMENT PLANT EQUIPMENT

Equipment within the water treatment plant must be properly maintained if operations are to run smoothly and efficiently. W'th space being limited, we cannot provide detailed instructions on the maintenance of each type of equipment used in the water treatment plant. Bear in mind, therefore, that here we are primarily interested in general maintenance requirements for some of the common types of treatment plant equipment. For specific and detailed maintenance instructions, refer to the manufacturer's manual for the particular type and make of equipment concerned. This chapter also contains information on safety. In addition, you will be briefed on different types of water storage facilities and maintenance procedures applying to these facilities.

SOLUTION FEED CHLORINATORS

The maintenance operations described below are applicable to all gaseous chlorinators, regardless of type.

Some preventive maintenance practices are fundamentally a part of normal equipment operations. Follow these precautions:

1. When connecting chlorine valves or tubes to cylinders or equipment, use a new lead gasket each time, and use only one gasket in each connection.
2. Guard against condensation on chlorine cylinder walls by maintaining proper ventilation around the equipment. Condensation may corrode scales or other equipment. An electric fan may be sufficient to keep the equipment dry. CAUTION: Do not use direct heat to dry cylinder surfaces.

Chlorinators and all piping should be inspected daily for leaks. For chlorine leak detection, an unstoppered bottle of aqua ammonia (or an aspirator-type bottle) should be used near all joints, valves and piping. White fumes indicate chlorine leaks. Repair immediately, no matter how small, as they will increase in size and cause corrosion and damage which may become extensive. (Keep the ammonia bottle tightly stoppered when not in use.)

In addition to leak inspection, all parts and piping in contact with chlorine gas should be inspected daily to ensure that operation is satisfactory. This includes metering devices, valves, tubing, and so on, which should be disassembled and cleaned where necessary; the source of trouble should be determined; and faulty parts should be replaced at the first indication of weakening.

All chlorine valves should be opened and closed daily during inspection in order to prevent freezing of the threads. Force should never be used to close chlorine valves. Stuffing boxes should be checked and faulty valves repaired or replaced immediately.

Monthly, water strainers and pressure-reducing valves should be checked for proper operation. Float valves should be adjusted, if necessary, to ensure that the water is at the proper level and that leakage and splashing are at a minimum. Water flowing to wastes should not be excessive. The ejector capacity should be ample; if it is not, the ejector should be removed and cleaned with muriatic acid.

Hard-rubber threads or parts should be disassembled or operated quarterly to prevent "freezing" of joints and subsequent breakage during dismantling. Graphite grease should be used on threads before reassembly. CAUTION: Tools should not be used on hard-rubber parts (except a strap wrench, if necessary); threaded, hard-rubber parts should be hand-tightened.

Operation of the relief line should be checked daily; it should be open and contain no obstructions such as wasps' nests.

Weekly, the chlorinator cabinet and all parts should be cleaned, including the metering devices, where dirt may cause improper operation

Table 11-1. — Maintenance Procedures for Chlorination Equipment

Inspection	Action	Frequency
Operation maintenance	Insert new lead gasket in chlorine valves or tubes to cylinders or equipment.	V...........
Condensation on chlorine cylinders.	Ventilate....................	V...........
Chlorine leak detection	Use unstoppered bottle of aqua-ammonia to detect leaks; repair immediately	D...........
Gas system..............	Inspect, clean and replace faulty parts in piping, meters, valves and tubing.	D...........
Chlorine valves	Open and close valves to ensure that none are frozen in a set; check stuffing boxes, and repair or replace faulty valves or packing.	D...........
Chlorine feeder water supply ...	Clean water strainers and pressure reducing valves; adjust float valves and ejector capacity.	M ....
Hard-rubber threads, valves and parts.	Disassemble or operate; use graphite grease to prevent freezing; hand tighten only, do not use tools.	Q...........
Vacuum relief	Clean out any obstructions..........	D...........
Cabinet and working parts	Clean all parts where accumulation may interfere with proper operation.	W...........
Direct-feed chlorinators	Use same procedures as for solution feed machines where they apply.	....
Hypochlorinators	See table 11-2.................	....

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or produce an unsightly condition. Unpainted metal subject to corrosion should be painted, and covered with petrolatum or some other protective compound.

The maintenance operation frequency and schedule of inspections for chlorination equipment are presented in table 11-1. In regard to this and other tables used throughout the remainder of this chapter, note that the frequencies shown are suggested frequencies and may be modified by local command, as individual installation conditions warrant. The frequency code used in tables presented in our discussion is as follows:

D — daily
W — weekly
M — monthly
Q — quarterly

SA — semiannually

A — annually

V — variable, as conditions may indicate

NOTE: Use these tables as a guide, rather than a complete listing, of items to be checked and the procedures to use in correcting defects.

DIRECT-FEED CHLORINATORS

Direct-feed chlorinators require the same maintenance of gas piping and gas feeding mechanisms as described for solution-type feeders, but they do not require maintenance of equipment in contact with chlorine solutions, as there is no such contact.

DRY CHEMICAL FEEDERS

The instructions given apply to all types of volumetric and gravimetric dry feeders, including disk, oscillating, rotary gate, belt-type, screw, and loss-in-weight.

The following basic maintenance operations should be applied daily to all dry chemical feeders:

1. Clean the feeder, the feeder mechanism, and the feeder surroundings. Use a vacuum cleaner or brush to remove spilled chemicals or chemical dust. Make certain that the orifice, knife edges, scrapers, shakers, and openings are free of chemical accumulations in volumetric feeders; and that both belt rolls and belt, in belt-gravimetric feeders, are free of chemical accumulations.

2. Check the feeder for general performance. Note and investigate unusual noises. Observe the condition of electrical wiring, fuses, and connections. Check for oil drips and general

Table 11-2. — Maintenance Procedures for Dry Chemical Feeders

Inspection	Action	Frequency
Dry feeders	Remove chemical dust accumulations; check feeder performance; check for loose bolts; clean solution tank of accumulated sediment; lubricate moving parts.	D.
Drive mechanisms and moving parts.	Service and lubricate	Q.
Calibration	Check feed-rate accuracy and adjust, as necessary	M
Feeders out-of-service	Clean, remove all chemicals from hopper and feeder mechanism.	V.
Disk feeders	Clean rotating disk and plow.	M
Oscillating feeders	Check and adjust mechanism and adjustable stroke rod.	M
Rotary gate feeders	Clean pockets of star feeder and scraper.	M
Belt-type feeders	Check vibratory mechanism, tare-balance, feeding gate, belt drive and belt; calibrate delivery.	M
Loss-in-weight feeders	Check feeder scale sensitivity, tare-weight and null balance.	M
Screw feeders	Clean screw, check ratchet drive or variable speed drive.	M
Lime slakers	Clean dust-removal and vapor-removal equipment; remove clinker.	D.
	Clean equipment; wipe off feeder; check operation of vapor remove equipment; clean compartments.	W
	Repair agitators, stirrers and heat exchanger baffles.	M
Dust collectors		
Motors	Lubricate motors	V.
Filter bags	Check condition and attachment. Securely attach sound bags; replace damaged or torn bags.	V.

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deterioration. Make such repairs as are necessary to overcome deterioration and lack of good performance.

3. Wipe all parts of the feeder and inspect for loose bolts, cracks, defective parts and leaks. Make the necessary repairs to eliminate undesirable conditions.

4. Check the solution tank for sediment or undissolved chemical; remove accumulated material. If the dissolver is lined with asphalt, check the lining which should not be skinned away from the steel. Follow the manufacturer's instructions to repair such linings.

5. Quarterly, service moving parts and lubricate, in accordance with manufacturer's instructions.

The maintenance operation frequency and schedule of inspections for dry chemical feeders are presented in table 11-2.

Table 11-3. —Maintenance Procedures for Liquid and Solution Chemical Feeders

Inspection	Action	Frequency
Pot feeders		
Flow through pot	Determine amount of chemical fed to ascertain if flow through pot is effective.	D.
Sediment trap	Clean trap and check needle valve	M
Chemical pot	Clean pot and orifice.	SA
Differential solution feeders		
Chemical storage tank	Inspect and clean	SA
Oil volume	Check and replenish	SA
Pitot tubes and needle valve.	Check and replace as necessary	A
All equipment	Paint as necessary	V.
Decanter or swing-pipe feeder		
Swing-pipe	Check to make certain it does not bind	M
Motor ratchet, pawl, reducing gears.	Check and lubricate	SA
Rotating dipper feeder		
Motor	Follow manufacturer's instructions	V.
Transmission	Change oil after 100 hr. operation	100 hr
	Drain and flush, clean interior and refill	SA
Shaft bearings	Lubricate	W
Drive chain	Clean, check alignment; check sprocket teeth; lubricate chain and sprockets.	M
Agitator	If used, clean and lubricate according to manufacturer's instructions.	V.
Belt drives	Check alignment, tension and inner cords of belt drives.	M
Dipper and float valve	Check dipper clearance and adjust float valve setting.	SA
Proportioning pumps (hypochlorinators).		
Operator inspection	Inspect sight feeders, rate of flow, piping, joints.	D.
Feeder	Clean feeder	W
Solution tank	Clean	M
Linings	If cracks occur, special linings should be repaired.	A.

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SOLUTION FEEDERS

Maintenance of pot-type solution feeders consists of daily operation inspection, monthly cleaning, and annual overhaul.

Daily operator inspection includes observations of the amount of chemical feed to determine whether flow through the post is effective.

Cleaning of the sediment trap and checking of the valve should be done at monthly intervals.

Cleaning of the chemical pot and orifice should be done twice a year.

Annual overhaul includes cleaning and painting of the pot feeder and appurtenances.

With the decanter or swing-pipe feeder, the swing-pipe should be checked monthly. The reducing gears, pawl, ratchet, and motor should be checked semiannually and overhauled annually, or as necessary. Overhauling includes cleaning, repairing, and painting all parts that require attention.

The maintenance operation frequency and schedules of inspection for liquid and solution chemical feeders are presented in table 11-3.

ION-EXCHANGE UNITS

An ion-exchange unit is illustrated in figure 8-16. Some of the maintenance procedures applicable to this type of unit are given in the following sections.

SOFTENER UNIT

The softener unit itself consists of a steel shell, containing a supporting grid in the bottom, a layer of gravel, and a layer of ion-exchange resin. The shell is equipped with openings, valves, and fittings.

Annually, the exterior of the shell should be cleaned and brushed with a wire brush, and then painted to protect it against corrosion.

Quarterly, fittings for the distribution of water and brine should be checked for possible obstructions, corrosion, and security fastness. Semiannually, each individual valve should be inspected and tested for leaks, and repacked, if necessary.

Semiannually, where multiport valves are used, they should be serviced and lubricated in strict conformance with the manufacturer's instructions. Lubricate this type of valve with grease as follows:

1. Add grease by pressure gun to each grease fitting, while the valve is set in "service" or "wash" position.

2. Turn valve one-half turn and add more grease.

3. Give valve several full turns to spread the lubricant.

This lubrication operation does not require that the softener be removed from service, but if the water flow is stopped, no grease will get into the water.

Quarterly, flush ion-exchange beds with chlorinated water containing at least 2 ppm of chlorine. Do not use water with a hardness greater than 170 ppm. and be certain that the pH of the water is approximately neutral. Also, follow these directions:

1. Check the bed surface for dirt, fines, organic growths, and for smoothness. Scrape excess foreign matter off and replace with new resin. If the surface is uneven, the gravel bed underneath is not distributing the wash water evenly. The remedy consists of removing the resin and gravel, and replacing both inproper fashion.

2. Check height of ion-exchange bed surface; remove or add ion-exchange resin to maintain proper elevation. (A low elevation will allow excess fines and foreign matter to accumulate on the surface of the bed; a high elevation allows resin to be washed out during backwashing.) Extra ion-exchange resin may be added through a 2- or 3-inch half-coupling (with brass plug), provided for that purpose in the upper head of the shell, or through the manhole cover plate.

3. Replace ion-exchange bed with new resin whenever the inspection indicates the need, or if the exchange capacity has decreased and cannot be restored by cleaning and special procedures recommended by the manufacturer.

4. Quarterly, probe through resin bed to determine the surface of the supporting gravel. The surface should be relatively even with a maximum difference of 4 inches between high and low spots. Any indication of shifting gravel bed, caking, or other difficulties, call for repair efforts. Uneven gravel may be raked smooth, through the open manhole, during backwashing operations.

When gravel needs to be removed for one reason or another, it may be cheaper to install new gravel than to remove, wash, and regrade old gravel. New gravel should be lime-free (do not use ordinary river gravel). If old gravel is reused, screen out all resin particles. Spraying with water is the best method of removing the resin from the gravel on the screen.

Replace or add new gravel in four layers. Fill the shell with water to the depth desired, then add the coarsest grade first; level the gravel layer to fill low spots; next, raise the water level to the next depth required and add the next smaller grade. Repeat the process; then add the resin to the desired depth and classify by backwashing the bed.

Annually, or as necessary, the condition of underdrains may be ascertained from the pressure drop across the underdrain system with a full backwash flow being discharged from the manhole. A greater pressure drop than existed at the time of installation indicates plugging underdrains; a lesser pressure drop indicates displace or corroded nozzles. Underdrains should be inspected, removed, cleaned, painted (where necessary) and replaced every 3 years.

Manifold-type underdrains should be inspected when gravel is removed. Remove several laterals at random and check for clogging. Where clogging is evident, remove all laterals, and clean mechanically, or by treatment with inhibited muriatic acid.

Plate-type underdrains should be removed, inspected, painted, and replaced, every 3 years; make certain that the clearance space between the plate and lower head is the same at all points.

REGENERATION EQUIPMENT

With regeneration equipment, the following procedures should be used:

1. The salt storage tank should be cleaned at varying periods, depending on the amount of insolubles in the salt, tank size, and the salt usage. Rock salt contains more insolubles than evaporated salt. The greater the salt usage, the more frequent the cleaning required.

2. The brine-measuring tank should be cleaned every 6 months, and both exterior and interior surfaces painted.

3. At annual intervals, the brine ejector should be cleaned, disassembled, and checked for erosion or corrosion; any clogging of piping should be removed before the ejector is reassembled and replaced.

The maintenance operation frequency and schedule of inspections for ion-exchange softening units are presented in table 11-4.

CLARIFICATION EQUIPMENT

Maintenance procedures applicable to clarification equipment are discussed below. The equipment involved includes mixers, flocculator basins, and sedimentation basins.

MIXERS

Mixing basins, whether baffled or mechanically stirred (rapid or flash), require attention and cleaning semiannually. Follow these procedures.

1. After draining, wash down the walls with a hose and flush the sediment to the drain. Repair spalled spots on walls or bottom, as necessary.

2. Check the valves or sluice gates for corrosion and ease of operation; clean and lubricate; paint valves as necessary.

Baffled Mixing Chambers

After cleaning the walls and bottom of baffled mixing chambers, brush the baffles and repair if necessary.

Rapid or Flash Mixers

Since rapid-mix devices revolve at great speed, DO NOT ATTEMPT TO CHECK THE ROTATION OF THE MIXER PADDLES, EXCEPT BY VISUAL OBSERVATION. When the mixing basin is empty, the condition of the paddles, bearing, drive shaft and motor should be checked, and they should be cleaned, lubricated and painted as necessary.

FLOCCULATOR BASINS

The following maintenance procedures apply to flocculator basins:

1. Monthly, during operation, check paddle rotation to assure that all flocculators are operating. Lower a light pole (bamboo fishing rod) into the water until the paddles strike the pole, giving evidence of paddle operation. Inoperative paddles may be caused by broken shafts or chains.

2. Semiannually, drain and clean the basin, walls, and floor; inspect the flocculator mechanism, the drive, bearings, gears, and other mechanical parts; clean and lubricate. Especially check underwater bearings for silt penetration. Replace scored bearings. Paint mechanism parts, where necessary.

Table 11-4. — Maintenance Procedures for Ion-Exchange Softening Units

Inspection	Action	Frequency
Softener unit		
Shell	Clean and wire brush; paint	A.
Valves and fittings	Check for obstructions, corrosion and fastness.	Q.
	Check for leaks; repack if necessary	SA.
Multiport valves	Lubricate with grease; follow directions for lubrication procedure.	SA.
Ion-exchange medium	Check bed surface for dirt, fines and organic growths; remove foreign matter and add resin to desired level.	Q.
Gravel	Probe through resin to determine gravel surface; level gravel surface with rake during backwash flow; replace gravel when caked, or if resin is being lost to effluent; wash and grade gravel and place in four separate layers; use new lime-free gravel at discretion of inspector.	Q.
Underdrains	Check pressure drop through underdrains; if necessary, remove manifold or plate underdrains; clean and replace.	A or V
Regeneration Equipment		
Salt storage unit	Clean tank as necessary to remove dirt	V.
Brine tank	Clean out dirt and insolubles; allow to dry; paint both exterior and interior surface.	SA.
Ejector	Clean, disassemble, check erosion and corrosion; clear clogged piping; assemble and replace.	A.
Operating conditions		
Flow rates	Check rate of flow through bed; adjust controls to optimum rate, depending on type of resin.	Q.
Backwash rates	Check rate and adjust controls to optimum rate.	Q.
Pressure	Check difference between inlet and outlet pressures; if undersirable changes in pressure drop have occurred, seek cause and remedy.	Q.
Efficiency	Compare total softening capacity with previous inspection; determine cause of decrease, if any, and remedy situation.	Q.
Out-of-service softeners	Drain; keep synthetic resins damp; do not regenerate before draining.	V.

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SEDIMENTATION BASINS

All types of settling basins require the same basin maintenance, such as lubrication, cleaning, flushing, and painting. Basins, which incorporate proprietary mechanisms or devices, should be maintained in accordance with the manufacturer's instructions.

Revolving-Sludge-Collector Basins

Specific maintenance procedures for revolving-sludge-collector basins should be in accordance with the manufacturer's instructions. The procedures described here are the minimum required.

Regular lubrication is required where the basin is in continuous operation. Intermittent operation affects the lubrication schedule, making it possible to increase the interval between lubrication periods. If operation periods are intermittent and infrequent, the mechanism should be operated briefly between operating periods, and lubricated accordingly. Devices subject to wide seasonal temperature variations must have seasonal changes in lubricant grades, especially where summer grade oils thicken below freezing and reduce the flow capability. Daily or weekly lubrication of operating units is a part of operator inspection. The choice of lubricant and its frequency of application are established by the manufacturer or by local command.

The following items, where they exist in the equipment, require attention on a regular basis, as set forth in the following paragraphs:

1. The speed reducer should be inspected weekly to ensure that the oil is at the proper level, is free of water and grit, and has the right body. If a reducer runs hot during its operation, the oil level may be too high or too low. (Where the reducer is out of service for an extended period, make certain it is filled above the level of the seals to prevent the seals from drying out. Be sure it is tagged to reflect this condition. The reducer must be drained to proper level before being placed back in service.) Replace oil whenever necessary.

2. The drive head should be lubricated daily, and care taken not to overlubricate.

3. The worm gear oil level should be checked at least weekly, and the water drained from the housing monthly.

4. The turntable bearings should be lubricated at monthly intervals, and the oil changed twice yearly.

5. Lubrication procedures for chains depend on the design of the chain and chain guard. Inspect monthly and add oil as necessary; drain off the accumulated oil as necessary; and change the oil twice yearly.

6. Annular ball bearings and thrust bearings are generally lubricated daily and inspected monthly for condition of lubrication.

7. Center bearings, shaft bearings, bushings, and so on, are lubricated according to the manufacturer's instructions.

Tank equipment requires annual inspection. In this inspection the following items should be covered:

1. Check bolts and tighten nuts to maintain original alignments and adjustments.

2. Check for excessive wear of moving parts, including gears.

3. Flush and backblow sludge withdrawal line, using high pressure water or compressed air. NOTE: Do not allow waterline to be cross-connected to the drinking water supply system.

4. Check the plows or rakes and straighten them if necessary.

5. Check the motor condition, couplings, and service shear pins.

6. Clean equipment and paint as necessary.

If the equipment has an overload alarm, check it for operation. If the alarm sounds at any time, shut off the equipment, locate the source of trouble and rectify the situation. Under no conditions should the alarm switch be nullified in order to provide continuous operation under overload conditions. If the overload is caused by a sludge build-up leading to cutout of the starter switch or pin shearing, the tank must then be drained and the sludge flushed out.

Conveyor-Type Collector Basins

As with the revolving-sludge-collectors, specific maintenance procedures in conveyor-type collector basins are set forth in the manufacturer's instructions. Maintenance procedures on the tanks and structures are the same for this type of sedimentation basin as they are for the circular-type basin. Generally, the maintenance procedures applicable to gears, chains, sprockets, reducers, and so on, are also the same as those which apply to circular-type basins.

Cathodic Protection

Where aggressive water problems exist in water supplies, the sedimentation tank equipment may be protected by cathodic protection. Cathodic protection is a method of protecting metal surfaces, through the use of a direct current voltage, from corrosion. The voltage is applied so that the current tends to flow from the direct current source through the soil or water to the metal surface to be protected. This flow of current applies electrical energy that reverses the natural process of corrosion.

There are two well-known methods of cathodic protection: the impressed current system and the galvanic anode system. The impressed current system requires graphite rods and an external power source to establish a voltage of sufficient magnitude. The galvanic anode system, which requires no external power supply, incorporates the use of metallic anodes; such metals as magnesium, zinc, or aluminum may be used as the anode.

Cathodic protection systems may be maintained by activity personnel or by service contract. The Field Engineering Office will provide guidance in developing maintenance procedures, or in contracting for such services.

IMPRESSED CURRENT SYSTEMS. — Make inspections and necessary maintenance repairs at monthly intervals. Follow these procedures:

1. Check exterior of enclosure for rust, corrosion, or mechanical damage; check hinges and locks for inadequate lubrication, rust, or other deficiencies; check wiring and fastenings, and rectifier for broken or damaged insulation, and for rust or corrosion on conduit; and, check exposed wires and cables and all electrical connections for insecurity, frayed or broken insulation, and other deficiencies.

2. Check interior of enclosure for rust, moisture condensation, loose wiring, and signs of excessive heating. (Do not put hand or tools inside the enclosure.)

3. Check anode suspensions for rust, corrosion, bent or broken suspension members, frayed or broken suspension lines or cables, loose bolts, loose cable connections, and frayed or broken wiring.

4. Whenever necessary, replace or repair any item which will not pass inspection for continued service, and paint switch cans and exposed rectifier housing and other electrical gear as necessary.

SACRIFICIAL ANODE SYSTEMS. — The only maintenance required for a galvanic anode system is monthly inspection and potential tests to determine when replacement of anodes is necessary, and to ensure continuity of the electric circuit. The following procedures apply:

1. When an abnormal decrease in current output (or potential of the protected structure) occurs, the anodes should be inspected for excessive disintegration.

2. Check terminals and jumpers of test leads for rust, corrosion, broken or frayed wires, loose connections, and similar deficiencies. Tighten all connections.

3. Check the bushing supporting the anode for rust and corrosion. Where resistors are installed in the circuit, examine these units for corrosion, broken and frayed wires, and loose connections. Tighten all connections.

4. Check the anode suspensions for rust, corrosion, bent or broken suspension members, frayed or broken suspension lines or cables, loose bolts, loose cable connections, and frayed or broken wiring. Install new anodes when necessary.

As a safety precaution, do not bridge insulated couplings or break electrical connections without engineering advice.

The maintenance operation frequency and schedule of inspections for clarification equipment are presented in table 11-5.

FILTRATION EQUIPMENT

Maintenance procedures on both gravity and pressure filters are essentially the same, differing only in detail. Some of the maintenance

Table 11-5.—Maintenance Procedures for Clarification Equipment

Inspection	Action	Frequency
Mixing basins	Drain, wash down walls, flush sediment to waste line; repair spalled spots on walls and bottom; Check valves on sluice gates; lubricate and paint valves as necessary.	SA
Baffled mixing chambers	Clean baffles and repair as necessary	SA
Flocculator basins	Check paddle rotation to ascertain if any flocculators are inoperative.	M
	Clean and lubricate drive, bearings, gears, and other mechanical parts; check underwater bearings for silt penetration; replace scored bearings.	SA
Rapid (or flash) mixers	Check paddles; clean bearings and drive shaft; lubricate and paint as necessary.	SA
Revolving-sludge-collector basins.	Drain tank, check submerged parts	SA
Operating parts	Lubricate	D or W
Speed reducers and oil baths.	Remove water and grit, replace oil, as necessary	W
Drive head	Lubricate—do not overlubricate	D
Worm-gear	Check oil level	W
	Drain water from housing	M
Turntable bearings	Lubricate	M
	Change oil	SA
Chains	Drain off water, add oil as necessary	M
	Change oil	SA
Annular ball bearings	Lubricate	D
Center bearings, shaft bearings, bushings, etc.	See manufacturer's instructions	V
Tank equipment	Tighten bolts and nuts; check for excessive wear, flush and backblow sludge line, check motors, couplings, and shear pins; check rakes, clean and paint equipment.	A
Conveyor-type-collector basins.	Consult manufacturer's instructions.	V
Upflow clarifier	See manufacturer's instructions	V
Cathodic protection		
Rectifier-type	Check exterior and interior for condition; see manufacturer's instructions; repair, replace, or paint as necessary.	M
Sacrificial anodes	Check anode condition and all connections, and replace as necessary.	M

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operations for diatomite filters are similar to those for sand filters; others are not.

GRAVITY FILTERS

Regardless of the type of filter medium used (sand or anthrafilt), the material which is filtered out of the water must be removed from the filter at regular intervals.

Filter Media

During the course of daily backwashing, as an operating procedure, the operator should observe any conditions which may indicate a need for more complete inspection. The following procedures are minimal:

1. At monthly intervals, drain the filter to the surface of the filter medium; inspect the surface for unevenness, sinkholes, cracks and evidence of algae, mud balls, or slime.

If depressions or craters on the surface are of appreciable size, dig out the sand and gravel, and locate and repair any break in the underdrain system.

Mud balls are removed using the procedure outlines in chapter 9.

If sand shows evidence of algae, prechlorinate ahead of filters. Where severe algae growths exist on sand or walls, remove the filter from service and treat the filter with a strong hypochlorite solution. Add enough hypochlorite to produce 2 to 4 ppm of free residual chlorine in a volume of water 6 inches deep above the filter surface. Draw down the filter until the water level is just above the bed surface. Allow it to stand for 6 to 8 hours, then backwash the surface, and follow this by a complete backwashing. Repeat, if necessary.

2. Quarterly, during a backwashing period, probe the filter for hard spots and uneven gravel. Examine the sand below the surface by digging to gravel with the water drawn down to the gravel level. If clogged areas appear because of cementation of sand grains with mud balls, or because of carbonate deposits, or if the sand (or anthrafilt) grains have increased in size due to incrustation (e.g., in softening plants or where lime and ferrous sulfate are used for coagulation), clean the sand by treating the idle filter with an inhibited muriatic acid or sulfurous acid. The advice of the Public Works Officer should be obtained if the operator is unfamiliar with the use of these chemicals.

Add the inhibited muriatic acid at the surface and allow it to pass downward through the bed and out the filter drain, or "rewash" the line; or add it to an empty filter through a small tap on the bed side of the ash-water line.

Use sulfurous acid as follows: Allow the sulfur dioxide gas from a cylinder to discharge into the filter wash-water line while slowly filling the filter bed with wash water. Use one 150-pound cylinder to 6,000 gallons of water to produce a 0.3 percent solution. Allow it to stand for 6 hours.

Semiannually, ascertain any change in the rate of wash-water-rise, as determined during operating procedures and check sand expansion.

Semiannually, inspect the sand and, if visual inspection does not reveal the condition of the medium, locate the elevation of the top of the bed to determine if the bed has "grown" in depth. Also, remove a sand sample and analyze it, as follows:

Make a sampling tube 12-inches square by 36-inches deep. Force a tube to the gravel level and drain the bed. Remove the sand from within the tube.

Collect several such samples from well-scattered locations on the filter bed, mixing until about 2 pounds remain. Dry this sample, mix, quarter and reduce to a usable sample size.

Determine loss of weight of a 10-gram sample during acid treatment. Treat sample with 10-percent hydrochloric acid in a pyrex evaporating dish on a water bath for 24 hours. Replace acid loss during treatment period. Wash, dry and weight the sand. Determine the weight loss and compare it to the previous analysis.

From the remainder of the sand sample, remove 100 grams and run a sieve test. Compare the results to previous tests.

If either inspection, weight loss or sieve analysis shows growth of sand grains to a point where filtration efficiency is impaired, treat the sand as follows: Add inhibited muriatic acid at the surface and allow it to pass downward through the bed and out the filter drain, or "rewash" the line; or add it to an empty filter through a small tap on the bed side of the wash-water line. Adjust the water treatment process as necessary. If treatment is not effective, replace the filter medium.

Gravel

Gravel inspection includes these procedures.

1. At monthly intervals, check the gravel bed surface for unevenness, using a garden rake or pole as a probe during backwashing. If ridges or sinkholes are indicated, the filter may need overhauling.

2. Every 6 months, remove sand from an area about 3 feet square, taking care not to disturb the gravel. Examine the gravel by hand to determine if the gravel is cemented with incrustation or mud balls, or if it is not layered properly.

3. If any undesirable conditions exist to a marked degree, the sand should be removed and the filter gravel relaid. If unevenness or layer mixing is caused by a faulty underdrain system, repair it; if it is caused by faulty backwashing, correct the backwashing procedure.

Filter Underdrain System

Annually, or as observations indicate the need, the filter bottom should be inspected. Sand boils during backwashing, or sand craters on the surface, indicate trouble in the underdrain system, as does marked unevenness of the gravel layers. Inspection and treatment procedures are as follows:

1. To inspect the bottom, remove the sand over an area of about 10 square feet. Select an area where sand boils or other indications of trouble have been noticed. Place planking over the gravel to stand on, and remove the gravel from areas about 2 feet square. Check underdrains for deterioration of any nature. If underdrains need repair, remove all sand and gravel, make repairs to underdrain, and replace gravel and sand in proper layers.

2. Where underdrains are of the porous plate type, and are clogged with alum floc penetration, flood the underdrain system with a 2-percent sodium hydroxide solution for a period of 12 to 16 hours.

Wash-Water Troughs

At quarterly intervals, the level and elevation of troughs should be checked. Water should be drawn below the trough lips, the wash-water valve should be cracked, and any low points observed where water spills over the lip, before the lip is covered completely.

The troughs should be adjusted as necessary to produce an even flow throughout their lengths on both sides.

At semiannual intervals, metal troughs should be inspected for corrosion. If corrosion exists, the troughs should be allowed to dry, and then cleaned by wire brush and painted with a protective paint or coating.

Operating Tables

Operating controls for filter valves may be mounted on a console, panel, or table. The controls actuate the filter valves which may be powered either by hydraulic or pneumatic means. The controls may be connected to the valve mechanism either by mechanical, electrical, hydraulic, or pneumatic connections.

These maintenance operations should be performed weekly:

1. Clean the table, the console, or the panel inside and out, using soap and water, if necessary.

2. If mechanically operated, check the tension on the cables, or the chains, used for connection to the valve operator, or for connection to the valve position indicators.

3. If hydraulically operated, inspect for leaks and stop any leakage; if pneumatically operated, check tubing for possible leakage.

Transfer valves (4-way) and handles should be adjusted monthly to make certain that all filter valves open at the same rate. Packing glands should be tightened, or new packing added as may be necessary.

Transfer valves should be lubricated monthly with grease. They should not be over-lubricated; one-half turn of the grease screw (cup) should be sufficient.

The valve-position indicator should be inspected monthly and adjusted to ensure that it reads correctly in all positions.

The 4-way transfer valves in the table should be disassembled annually and any worn parts, seats or washers should be cleaned or replaced with new ones.

The inside of the table, console or panel should be painted annually to protect against corrosion.

Rate Controllers

Rate-of-flow controllers (see fig. 9-12) may be either direct-acting or indirect-acting.

With DIRECT-ACTING controllers, the following maintenance procedures apply:

1. Weekly, clean exterior, check for leakage through diaphragm pot, and lubricate or tighten packing to stop any existing leakage. Also, ensure that both the diaphragm and the control gate move freely between zero differential and the open and closed positions.

2. At intervals of one or more years, remove and disassemble the diaphragm pot, including the rubber diaphragm. If the water does not cause tubercles, this operation may not have to be done more often than once every 3 to 5 years. The term "tubercles" refers to small, more or less hemispherical lumps on the walls of the pipe, which increase the friction loss and, by reducing the velocity, also reduce the capacity of the pipe. Tubercles result from tuberculation, a condition which develops on the interior of ferrous pipelines, being caused by corrosive materials present in the water passing through the pipe.

3. Every 3 years, disassemble and service the controller gate and mechanism. Inspect the venturi throat. Paint or apply protective coating, as necessary.

With INDIRECT-ACTING controllers, the following maintenance procedures apply:

1. At weekly intervals, clean the outside of the controller; adjust the packing, lubricate or tighten the fittings as necessary to stop any leakage from the hydraulic cylinder, the controller valve, piping, or the pilot valve. Make sure that the knife edges seat correctly and are free of paint or other foreign matter. Also, be sure that the piston has free vertical travel and does not bind. Replace packing, if necessary.

2. Annually, disassemble, clean and lubricate the pilot valve. Remove foreign matter from the piston with a cloth. Never use an abrasive to clean the piston. Make certain that no foreign matter enters the pilot valve during the cleaning operation. Check for leaks or cracks in the diaphragm.

3. Every third year, disassemble and service the controller gate and mechanism; inspect the venturi throat and apply protective coatings where necessary. Check the hydraulic cylinders, and maintain them in accordance with the manufacturer's instructions.

Gages

Various types of indicating and recording instruments may be mounted on the operating table or control panel. Here we will take up one such device—the diaphragm-pendulum unit loss-of-head gage. Where the actuating mechanism is of this type, the general maintenance procedures given here apply. For a more detailed discussion of these procedures, consult the manufacturer's instructions.

The following operations are to be performed monthly.

1. Purge the diaphragm cases of air, and check the cable to be sure that it leaves the segment at a tangent to the lower end when a zero reading exists on the unit.

2. Remove dirt from the knife edges; if it is necessary, tighten the cam hubs on their shafts.

3. Drain mud from the mud leg. In doing this, flush the mud out of the water pipeline running from above the sand to the loss-of-head gage. Drain the mud leg until the water runs free of sediment.

Annually, inspect the diaphragms for leakage, and replace if necessary. (NOTE: Diaphragms in stock should be stored under water.) Also, disassemble the unit in order to clean and lubricate it when necessary. Check the working parts and the cables (they should be free of knots, splices, or fraying). Repack the stuffing box if it is leaking. Make certain that the knife edges rest solely on their edges, where the pendulum is hung vertically, and be sure that all cable ends are knotted tightly.

Piping and Valves

At monthly intervals, check for leaks at the joints; also, check the pipe hangers, and replace any that have deteriorated. Paint piping, valves, and hangers if necessary in order to prevent corrosion.

PRESSURE FILTERS

Except that the filter medium is housed in an enclosed pressure shell, pressure filters are constructed in the same way as are gravity filters with respect to the underdrain system, gravel, and the filter medium (sand or anthrafilt). Pressure filters need the same care and attention as do gravity filters. Since their backwashing operations cannot be observed, the filter must be opened regularly and inspected carefully. Follow these maintenance procedures:

1. Weekly, inspect piping and valves for leaks. Lubricate and repack valves if necessary.
2. Quarterly, open the pressure shell and inspect the filter bed surface. Follow these procedures:

A. Use a garden rake during backwashing while the manhole is open in order to test for mud balls in the lower part of the filter bed and for evenness of the gravel layer surface.
B. Determine if the sand bed level has changed since the last inspection by comparing the bed surface elevation with some reference point.
C. If the filter does not have a surface wash system, and shows evidence of mud balls, backwash it at the highest rate possible while jetting the surface with a stream of water from a high pressure hose nozzle.
D. Annually, open the filter, remove the sand from an area sufficient in size to permit the inspection of the gravel. If the sand or gravel distribution indicates nonuniform distribution of backwash water, the filter media and gravel may need to be removed, and the underdrain system checked.
E. Annually, clean and paint the exterior of the shell.
F. Every third year (or more often if necessary), the filter medium and gravel should be removed, and the underdrain system checked for the distribution of wash water, and repaired if necessary. Clean the underdrain system, and paint it or apply a protective coating to all parts subject to corrosion, including the inside of the shell. Replace the gravel and the filter medium.

DIATOMITE FILTERS

Most diatomite filter installations in potable water supply plants are of the pressure type, although there are vacuum-type filters that can be used in certain installations. In general, the maintenance procedures for cleaning the filter element are the same for both types. The following procedures apply:

At MONTHLY intervals, or as often as operating conditions indicate the need, check the filter elements. The need for cleaning is evident when the precoat has apparent bare spots on the elements. Causes of element clogging are iron oxide and managanese dioxide deposits and algae growths.

For iron oxide removal, treat the elements with a 0.5-percent solution of oxalic acid. Information is available from manufacturers on the amount of oxalic acid to use on different size units. The following procedures are used:

1. Start with an empty filter after a regular washing.
2. Close the drain valve and the main outlet valve; open the recirculation valve.
3. Fill the tank to a level covering the top of the elements.
4. Add the proper quantity of oxalic acid, and recirculate for 1 hour.
5. Drain and hose down the elements and the tank interior.
6. Close the drain valve; refill, circulate a few minutes, and then drain again. If the cleaning is not completely effective, repeat the procedure.

The procedure for manganese dioxide removal is the same as for the removal of iron oxide, except that anhydrous sodium bisulfite must be added to the solution (see the manufacturer's instructions for the correct amount).

To remove algae growths, add a 12-1/2 percent hypochlorite solution to the tank volume after filling the tank to the proper level (see the manufacturer's instructions for the proper amounts to use for different sized units).

SEMIANNUALLY, check the piping and valves and appurtenant equipment, including the body feed equipment. Make whatever adjustments the manufacturer's instructions indicate to be necessary.

Clean and paint all exterior surfaces ANNUALLY, if necessary.

The maintenance operation frequency and schedule of inspections for filtration equipment are presented in table 11-6.

AERATION EQUIPMENT

Maintenance procedures applicable to some of the common types of aerators which may be available to your activity are presented below.

Table 11-6. —Maintenance Procedures for Filtration Equipment

Inspection	Action	Frequency
Gravity filters		
Filter media	Inspect surface for unevenness, sinkholes, cracks, algae, mud balls or slime.	M
	Dig out sand and gravel at craters of appreciable size; locate and repair underdrain system breaks.	V
	Chlorinate to kill algae growths	V
	Probe for hard spots and uneven gravel layers; if present, treat filter with acid.	Q
	Check wash water rise rate and sand expansion during backwashing.	SA
Filter media	Check sand condition for grain size growth; sample sand, determine weight loss on acid digestion, and run sieve test; acid-treat if necessary, or replace sand, if necessary.	SA
Gravel	Check elevation of gravel surface	M
	Examine gravel for incrustation, cementation, alum penetration, mud balls; if necessary, remove, clean and relay gravel.	SA
Underdrain system	Remove sand from area of 10 sq. ft., and inspect 2 sq. ft. area of gravel (or more); if underdrains are deteriorated, remove all sand and gravel, repair underdrains, replace gravel and sand.	A
	If porous underdrain, clogged by alum floc, treat with 2% sodium hydroxide solution for 12 to 16 hrs.	V
Wash water troughs	Check level and elevation, adjust	Q
	Check for corrosion; if present, dry troughs, wire brush, and paint.	SA
Operating tables	Clean table (console or panel) inside and out.	W
Cables	Adjust tension	V
Hydraulic lines (or pneumatic) pneumatic).	Check for leakage	V
4-way valves	Adjust, tighten packing glands or add new packing.	M
Transfer valves	Lubricate with grease	M
Valve position indicator.	Adjust, if necessary	M
4-way transfer valves	Disassemble, clean, lubricate and replace worn parts.	A
Table	Paint inside	A

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Table 11-6. — Maintenance Procedures for Filtration Equipment — Continued

Inspection	Action	Frequency
Rate controllers.		
Direct-acting	Clean exterior, check diaphragm leakage, tighten packing, check freedom of movement and zero differential.	W
Diaphragm pot	Disassemble, clean and replace	A or V
Controller mechanism	Disassemble, service; clean venturi; paint surfaces needing protection.	Every 3 yrs.
Indirect-acting	Clean outside, adjust packing, lubricate and tighten fittings; check knife edges, check piston travel; repack as necessary.	W
Pilot valves	Disassemble, clean and lubricate; check piston travel; clean piping and strainers; check for leaks in diaphragm.	A.
Controller mechanism	Disassemble, service; clean venturi; clean hydraulic cylinders; paint as necessary.	Every 3 yrs.
Mechanically-operated loss-of-head gages.	Check zero setting; adjust stop collars or cable; release air from float chamber.	M
Mud leg	Flush out sediment	M
Float chamber	Remove float, clean; remove mercury, clean and replace; check pressure pipelines; paint interior and exterior.	A.
Diaphragm-pendulum loss-of-head unit.	Check zero setting; purge diaphragm cases of air; check cable at segment; remove dirt from knife edges; tighten can hubs on shafts; drain mud from mud leg.	M
Pipelines to diaphragm.	Check for free flow and absence of incrustation.	SA.
Diaphragm-pendulum unit.	Check for leakage; disassemble unit, clean and lubricate; check working parts, cables; repack stuffing box; check knife edges.	A.
Mercury-float-type rate-of-flow gages.	Check at zero differential, adjust indicator arm and recording pens; check stop collars on cables.	M
	Check accuracy and percent error; if greater than ±3% adjust.	SA.
Pressure Lines	Check and clean as necessary.	SA.
Float chamber	Clean float and mercury; paint all parts requiring protection.	A
Piping and valves	Check for joint leaks; check pipe hangers, replace if necessary; paint, as necessary;	M

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Table 11-6. — Maintenance Procedures for Filtration Equipment — Continued

Inspection	Action	Frequency
Pressure filters		
Piping and valves	Check for leaks; lubricate and repack valves as necessary.	W
Filter bed	Open pressure shell, check sand surface for mud balls, unevenness; check sand surface elevation; remove mud balls.	Q
	Remove sand in sizeable area and check gravel.	A.
Pressure shell	Clean and paint exterior	A.
Underdrains	Remove sand, check gravel; remove gravel, check underdrains; clean, paint and repair; replace gravel and sand.	Every 3 yrs.
Diatomite filters		
Filter elements	Check for clogging; clean as necessary (e.g., treat to remove iron oxide, manganese dioxide and algae).	M
Piping and appurtenant equipment.	Check for leaks, clean and repair auxiliaries.	SA
Exterior surfaces	Clean and paint	A.

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WATERFALL AERATORS

The maintenance of waterfall type aerators (cascade or step, and tray or splash pan) is as follows:

ONCE A WEEK, inspect the aerator surfaces for algae or other growths, precipitated iron oxide, and for nonuniformity of water distribution and staining. Clean when necessary. Treat with copper sulfate or hypochlorite solution to destroy growths.

SEMIANNUALLY, clean and repair tray aerators, removing the trays as necessary. Inspect the coke tray aerators for biological growths and coke deterioration. Replace the coke if the cleaning is not effective. Repair the screens and enclosures if necessary.

Repair or replace the surfaces on cascade or step aerators ANNUALLY if necessary.

INJECTION OR DIFFUSER AERATORS

Injection or diffuser aerators may be either porous medium design or injection nozzles.

Porous Ceramic Diffusers

The maintenance of porous ceramic diffusers — plate or tube — is carried out in the following manner:

1. Upon evidence of the nonuniform distribution of air, or clogging that impairs operation, dewater the tank, inspect and clean diffusers if necessary.

2. Every 6 months, drain the aeration tank and inspect the diffusers for joint leaks, broken diffusers and clogging. Porous ceramic diffusers may suffer clogging of either the water side or the air side (underside).

A. Water side (porous plate diffusers). Use oxidizing acids to clean organic growths from plate surface. (NOTE: Chlorine gas introduced into the air line at intervals between inspections will help hold down organic growths.) Removable plates should be soaked in 50-percent nitric acid. Plates grouted in place cannot be treated with nitric acid; use chromic acid (made by adding 1 gram of sodium dichromate to 50 ml of sulfuric acid). Pour approximately 2 fluid ounces on each plate on two succeeding days. CAUTION: These acids must be handled carefully. Particularly, DO NOT pour water into sulfuric or chromic acid, as it will explode and splatter the acid over the person handling it. Such acid will cause severe burns to the skin and clothes. ALWAYS pour acid SLOWLY into the water, while stirring continuously. Acid treatment should be done only upon approval of the Public Works Officer and under the supervision of a chemist or other qualified personnel.

B. Air side (porous plate diffusers). If clogging is caused by iron oxide particles from pipes, treat this condition with a 30-percent solution of hydrochloric acid. If clogging is by soot, oil, or dust from improperly filtered air, remove the diffusers and burn off the extraneous material in a furnace.

C. Porous ceramic tubes. Tubes may be removed and cleaned by soaking in acids or by burning (as described for porous plate diffusers).

Porous Saran-Wound Tube Diffusers

These diffusers should be inspected and cleaned semiannually as necessary. This material cannot be subjected to strong acids or heat. It must be scrubbed with a brush and soap or detergent.

Injection Nozzles

Injection nozzles should be inspected and cleaned semiannually as necessary. Diffuser nozzles on header lines may become clogged from deposition inside, from iron oxide particles, or on the outside from organic growths. Clogging from the inside may necessitate the removal of the individual nozzles for cleaning. Chlorine gas injection into the air-line header between inspections will hold down organic growths. At inspection periods, if growths are present, scrub them off with a brush and detergent solution to which hypochloride has been added.

SPRAY NOZZLE AERATORS

The following procedures apply to this type of equipment:

At WEEKLY intervals, check the nozzles for clogging, and clean when necessary. Remove the nozzles only when necessary. Check for adequate spread.

QUARTERLY, check air-line manifolds, remove caps and clean out sediment; check for joint leaks. Check pipe supports, replace or repair, and paint as necessary.

If spray fences exist, repair and paint them on an ANNUAL schedule.

BLOWERS AND ACCESSORY EQUIPMENT

Where injection aeration is used, adopt the following procedures.

DAILY, lubricate the blower or compressor according to the manufacturer's instructions. Check output pressures.

WEEKLY, inspect the air filters; clean, repair or replace them as necessary.

ANNUALLY, open the blower or compressor and inspect for internal erosion or deterioration; repair as necessary. Paint exterior surfaces.

Maintenance operation frequencies and the schedule of inspections for aeration equipment are presented in table 11-7.

SAFETY

The operation of water treatment plants is a hazardous occupation fraught with dangers from noxious gases and vapors, physical injury, and infections. Work should be carried on only under the supervision of an experienced workman or operator who is trained in first aid and is familiar with all the occupational hazards of the work.

Every effort should be made to promote good housekeeping at the water treatment plant. Tools should be returned to their proper place when no longer needed. Empty bottles or other such objects should not be left lying around on the floor where someone is likely to trip or fall over them. See that the plant is kept neat and clean at all times. Among other things, ensure that passageways are kept free of greases and oil.

Switchboards must not be used as clothes racks. Special care must be taken not to work around electrical apparatus or wiring with wet hands, or in wet shoes or clothes.

Workmen on night watch or otherwise required to perform duties alone around water treatment plants should be required to be capable of swimming at least 100 feet while dressed in the usual type of work clothing.

When an employee is performing any duties inside the tank guardrail, he should wear a safety belt and lifeline attached to the guardrail.

Guardrails should be maintained around all water treatment plant open tanks. Hand-holds

Table 11-7.—Maintenance Procedures for Aeration Equipment

Inspection	Action	Frequency
Waterfall type aerators (cascade).	Inspect aerator surfaces; remove algae; clean.	D
Waterfall type aerators (tray).	Clean and repair trays; clean coke or replace.	SA
Waterfall type aerators (cascade).	Repair or replace surfaces as necessary.	A
Injection aerators		
Porous ceramic plate or tube.	Check discharge pressure; if clogging is evident, dewater tank, clean diffusers.	V
Porous ceramic plate or tube.	Drain aeration tank, check for joint leaks, broken diffusers, clogging.	SA
Water side of ceramic diffusers.	Clean with acid, in place, or remove and soak in acid.	SA
Air side of ceramic diffusers.	If plates are clogged by iron oxide, treat with HCl; if clogged by soot, oil, etc., remove diffusers and burn.	SA
Saran wound diffusers	Clean by scrubbing with soap or detergent.	SA
Nozzles	Clean nozzles inside and out	SA
Spray nozzle aerators		
Nozzles	Check for clogging; clean, remove if necessary to clean.	W
Manifolds	Remove caps and clean out sediment; check pipe supports, repair, as necessary; paint as necessary.	Q
Spray fence	Paint	A
Blowers and accessory equipment.		
Compressor or blower	Lubricate, check output pressure for indications of clogging.	D
Air filters	Clean, repair or replace	W
Compressor or blower	Open, inspect, clean, repair and paint exterior surfaces.	A

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or suitable ladders should be maintained on one side wall of each open tank. Suitable handrails 6 to 12 inches above the waterline should be maintained on each side of open tanks.

RESPIRATORY PROTECTIVE APPARATUS

In water treatment and sewage maintenance work you may use various types of respiratory protective apparatus; such as self-generating oxygen breathing apparatus and self-contained oxygen breathing apparatus. Personnel directed to use this equipment should practice regularly with it in order to become proficient in putting it on quickly and accustomed to breathing through it.

Self-generating oxygen breathing apparatus (OBA) gives respiratory protection in moderately and extremely high concentration of toxic gases or vapors or in atmosphere deficient in oxygen. This equipment includes the following parts: a canister that holds chemicals to absorb carbon dioxide and moisture from the exhaled air and generates oxygen; and a breathing bag that serves as an air reservoir and a cooling chamber for inhaled air. Inhalation and exhalation check valves are integral parts of this equipment. Figure 11-1

3.165
Figure 11-1.—Self-generating oxygen breathing apparatus.

shows a self-generating oxygen breathing apparatus. Note: Do not use the OBA in an explosive area as it is a fire hazard.

Self-contained oxygen breathing apparatus (fig. 11-2) is effective for limited time use against any poisonous gas or oxygen-deficient atmosphere, such as when inspecting long, large sewers where a hose mask would be impractical. This equipment generally includes the following parts: a steel cylinder or bottle containing

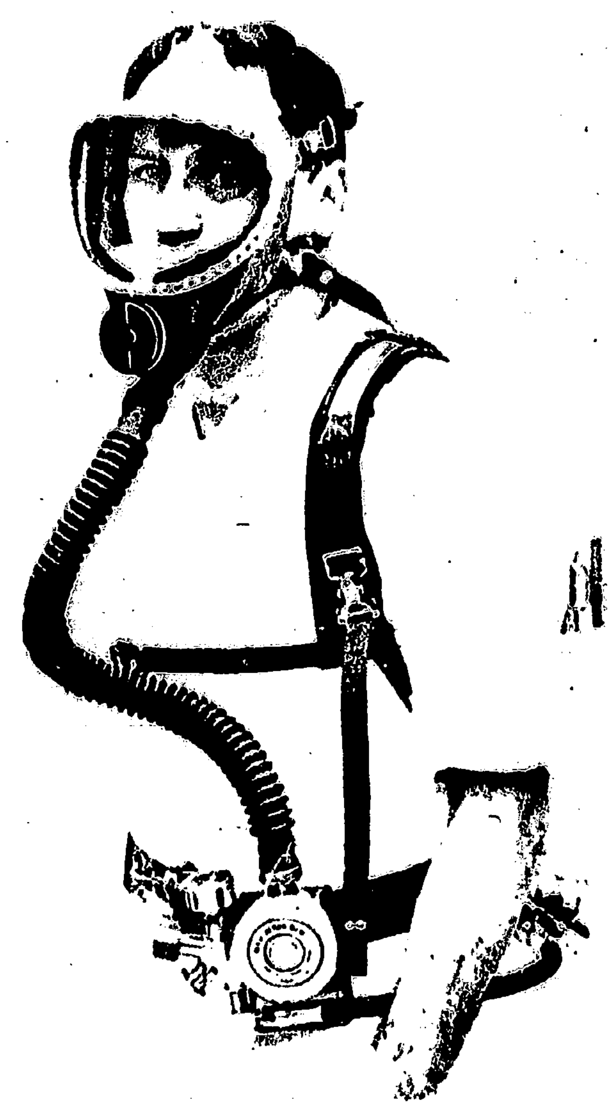

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Figure 11-2.—Self-contained oxygen breathing apparatus with bottle.

oxygen under high pressure and a reducing valve to supply oxygen as needed at slightly higher than normal pressure.

Respiratory apparatus should be kept in accessible locations, but in quarters segregated from probable gas hazards.

CHLORINATION SAFETY PRECAUTIONS

Specific precautions to be observed in handling ammonia, chlorine and chlorine-yielding compounds were presented in an earlier chapter on water treatment plants. A number of chlorination safety precautions which also should be observed are given below.

Provide self-generating oxygen breathing apparatus or self-contained oxygen breathing apparatus designed to cope with chlorine.

Maintain only the supply of chlorine in any chlorinator room that is sufficient for normal daily demands. Store the main supply in a detached noncombustible building or in a fireproof room which is vented only to the outside and which is separated from the main part of the building. Keep the chlorinator and chlorine storage buildings or rooms locked to prevent the entrance of unauthorized personnel and restrict these areas from any other use.

Allow only reliable and trained personnel to handle chlorine.

Handle containers carefully to avoid dropping or bumping them.

Avoid hoisting containers as much as possible; if hoisting is necessary, use safe lifting clamps.

Store cylinders in a cool place, away from dampness, steam lines and fire, and in an upright position secured from tilting and falling.

Keep protective valve caps on containers when not in use; never tamper with safety devices on containers.

Never connect a full cylinder to a manifold with another cylinder, unless temperatures of both are approximately the same.

When not withdrawing chlorine or when cylinders are empty, keep the valves closed.

Disconnect valves as soon as containers are empty, and check for chlorine leaks at the valve outlets. Test for leaks by passing an unstoppered bottle of strong ammonia solution around the valve. White fumes of ammonium chloride will appear if there is any leakage. Leaks around fittings, connections and lines can be detected in the same way. Do not apply ammonia solution to plated metal parts as it will remove the plating.

When chlorine is noticed in the atmosphere, workers should avoid panic, refrain from coughing, keep the mouth closed, avoid deep breathing, keep the head high, and withdraw at once from the affected area. Only qualified personnel with suitable respiratory equipment will be assigned to investigate and correct the cause of chlorine leaks. If chlorine is being discharged, close the container valve immediately. If chlorine is escaping in liquid form, turn the containers so the chlorine escapes as gas, which will reduce leakage. Do not apply water to the leak; this practice is hazardous and results in corrosive action that may increase the leakage.

The handling of a persistent chlorine leak in a plant is best left to the chlorine supplier.

Never apply flame, a blow torch or other direct heat to chlorine containers; discharge them in a room with a temperature of about 70° F.

Never ship a defective or leaky cylinder unless it is completely empty. Paint "DEFECTIVE" plainly on all such cylinders.

Follow all regulations on shipping, storing, and using compressed-gas cylinders.

Provide proper means of exit from areas where chlorine is stored or used.

Never use a chlorine cylinder for any purpose other than holding chlorine gas.

FIRST AID FOR CHLORINE POISONING

Should any of the plant personnel become seriously affected by chlorine gas, or be overcome by its action, the following steps should be taken:

1. Remove the affected person at once to open air and away from gas fumes.
2. Call a physician.
3. Place the patient flat on his back with his head slightly elevated. Keep him warm, and do not excite him.
4. If the patient is conscious, give him one-half teaspoonful of essence of peppermint, or a moderate stimulant. Do not give him milk as milk or cream will usually curdle in the stomach and cause vomiting, which adds to the discomfort of the patient.
5. Insofar as he is able, the person affected should resist the impulse to cough.
6. If the patient is unconscious and not breathing, apply artificial respiration.

EMERGENCY TREATMENT.—For almost any chemical spillage on personnel, quick, thorough and continued flooding of the affected body area with water is the best general first aid measure. Call a medical officer if chemical burns are involved, and ALWAYS if the eyes have been affected by the accident.

HANDLING LIME

Operators must be particularly attentive to the common sense rules of good housekeeping in handling lime. This chemical should be carefully stored in a dry area away from any combustible materials. An efficient dust-collecting system should be used whenever dust is present at handling points. A dry-pickup vacuum cleaner should be employed for removing dust around unloading equipment and chemical feeders.

Protective clothing should always be worn for personal safety in case bags break or the dust collection system fails. The proper dress is heavy denim clothing with long sleeves, heavy gloves, bandanas, and trousers tied around the shoe tops. Chemical goggles and suitable dust masks should be worn. Any exposed skin areas should be covered with protective creams.

CAUTIONS: Particular caution must be observed to avoid accidental contact of quicklime with water, and when working with freshly slaked lime because of the heat generated when the lime is mixed with water. Serious skin burns and eye damage can be caused by contact with hot lime solution. OPERATORS SHOULD ALWAYS WEAR CHEMICAL GOGGLES OR FACE SHIELDS WHEN OPERATING LIME-FEEDING EQUIPMENT.

STORAGE FACILITIES

The operation of storage facilities in the distribution system is largely a matter of maintaining sufficient levels through adequate pumping, and controlling water flow through appropriate valves.

Live storage, where water is constantly circulating from the supply into the distribution system, is preferred to noncirculating storage because the latter depletes the chlorine in the water and allows tastes and odors to develop. If such dead storage is necessary, the operator must maintain a close watch on chlorine residuals and the development of odors and tastes, and report conditions regularly to higher authority.

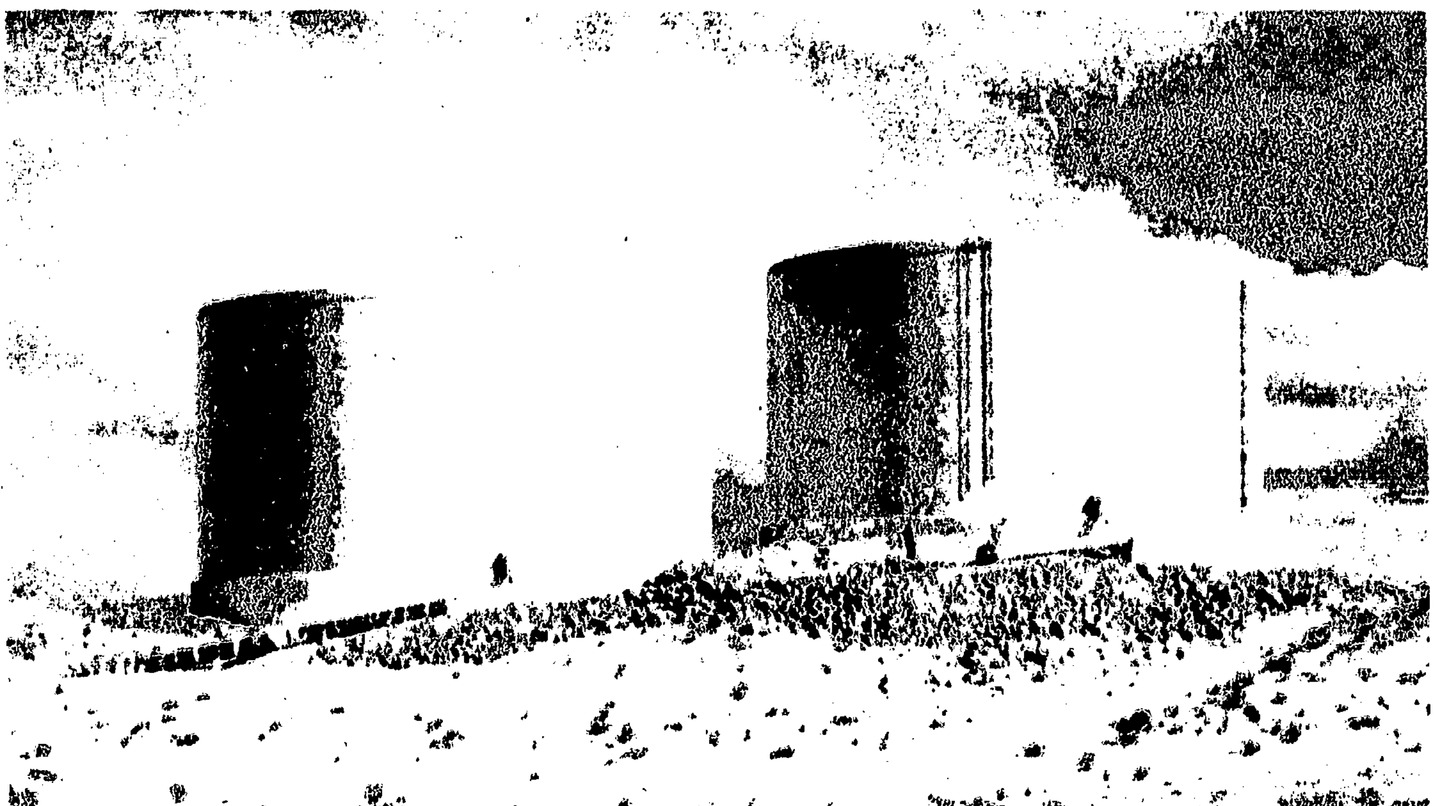

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Figure 11-3. —Ground storage reservoir.

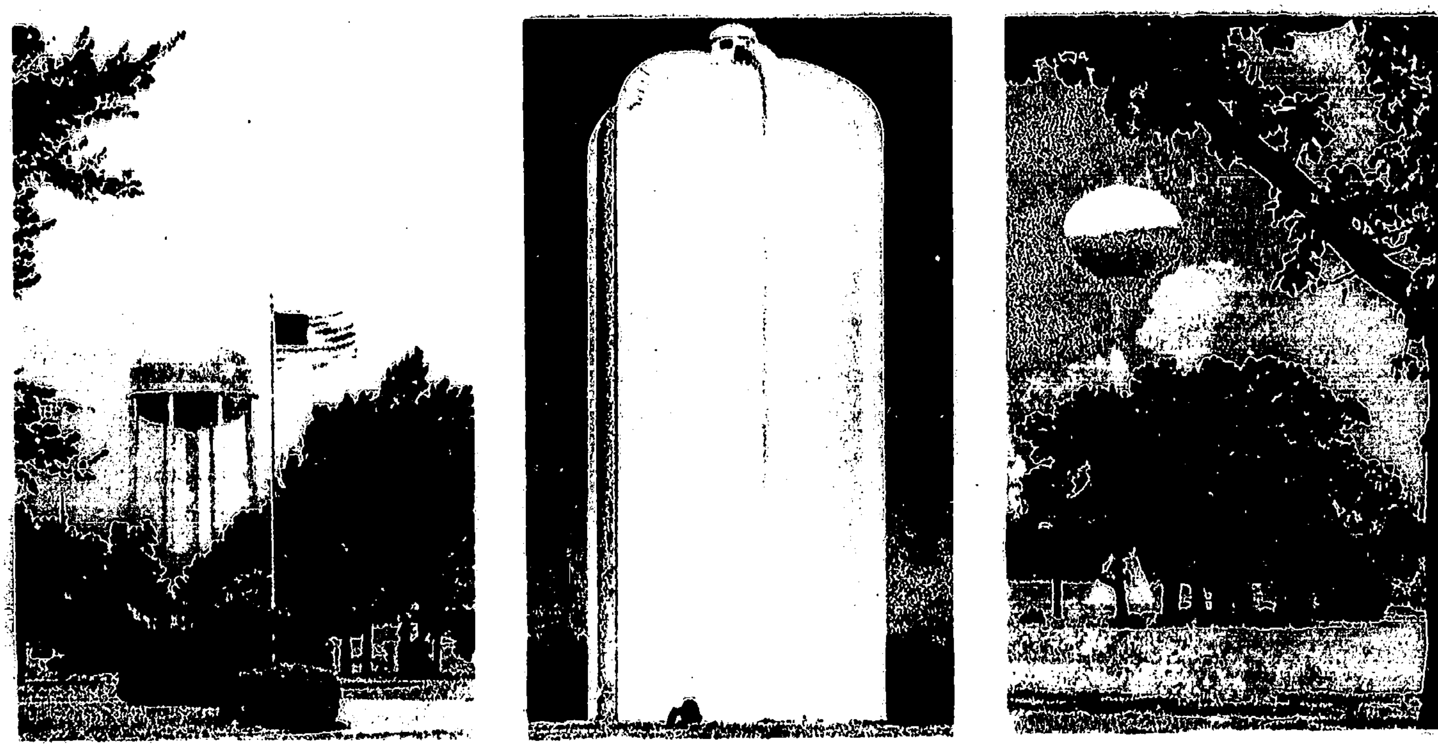

Figure 11-4. — Three types of elevated storage tanks. 54.255X

TYPES OF STORAGE

Facilities used for storage of water include open reservoirs, underground reservoirs, and elevated storage tanks. Ground storage reservoirs may be the same or similar to those shown in figure 11-3. Three types of elevated storage tanks, which you may find at naval activities are pictured in figure 11-4. You may also see standpipes, like the one shown in figure 11-5, used at some activities. Standpipes are, in effect, ground level storage tanks. The distinguishing characteristic of a standpipe is a relatively small diameter and extra height to provide head. Under no conditions should the amount of stored water be reduced to a point below that necessary for firefighting. Daily records, maintained by the operator, help ensure against such a condition.

Pneumatic water tanks are usually found in use at smaller installations. They consist of a pressure vessel partly filled with water, with a compressor unit attached to produce the desired water pressure. Pneumatic tanks may be located within buildings, on outside surface locations, or underground. While the operation of these units is usually automatic, the operator is responsible for the effective operating of pressure equipment. The manufacturer's instructions should be consulted for methods of starting stopping, and operating this pressure equipment.

MAINTENANCE OF STORAGE FACILITIES

Two basic factors affect the maintenance procedures to be followed with respect to storage facilities. These factors are: the materials of construction (concrete or steel), and the location of the tank (at ground level, below ground or elevated).

Foundations

All tanks have foundations of concrete, or steel. Each material has its own maintenance procedures.

CONCRETE foundations should be inspected semiannually for settlement, cracks, spalling, and exposed reinforcing. If deterioration has set in, the foundation should be repaired with a mixture of one part cement to one part sand.

WOOD foundations and pads should be inspected for split members, rot, termite infestation and for direct soil contact of untreated wood. Any repairs necessary to remove the undesirable condition should be made.

Maintenance procedures for steel foundations are similar to those given later in this chapter for elevated storage tanks.

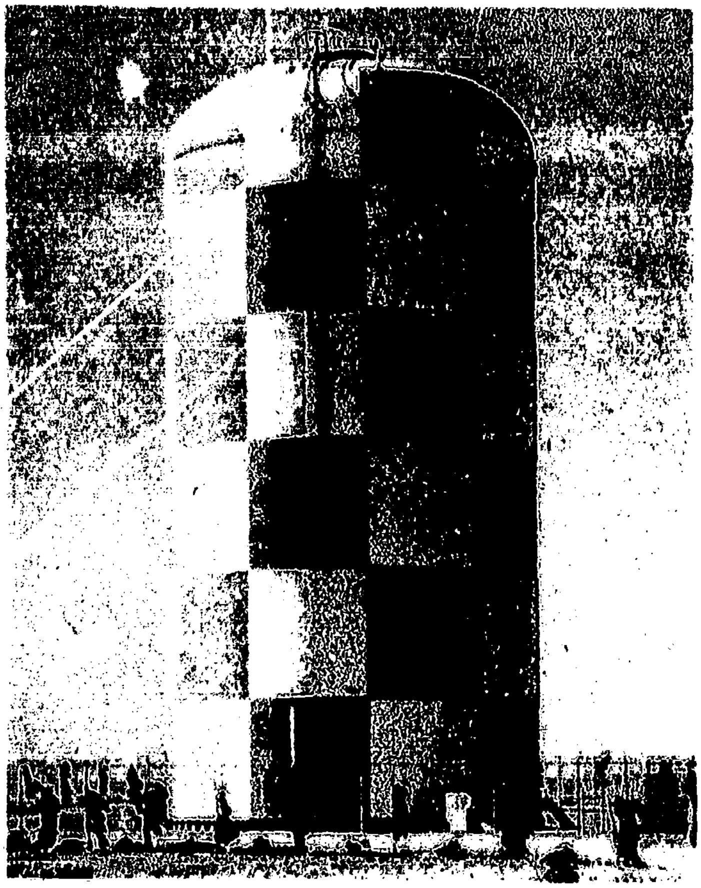

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Figure 11-5. —Standpipe.

Concrete Storage Tanks

Concrete storage tanks may be either prestressed or nonstressed design. There is little difference in the maintenance procedures, which depend mainly on the location of the tank — above ground or below ground.

GROUND LEVEL STORAGE. —Each spring, ground level storage facilities should be inspected for watertightness and structural conditions and repairs made as necessary; at other intervals the maintenance procedures set forth in the following paragraphs should be performed.

Semiannually, exterior walls should be marked where leakage or seepage occurs. Every spring, they should be inspected for seepage or leakage from cracks, breaks or cracks in the interior seal membrane. Dewater the tank and check both the interior and exterior surfaces for spalling caused by frost action, as well as settlement, cracks, and exposed reinforcing.

All loose, scaly, or crumbly concrete should be removed and the wall patched with rich cement grout after wetting and painting with portland cement slurry. Hardened grout should be painted with iron waterproofing compound, or a similar preparation.

In repairing cracks, 1/4-inch width and 1-inch depth should be chipped out. The cleaned crack should be moistened, and painted with portland cement slurry. The crack should be filled with a rich cement grout dry enough to stay in place in the crack, but not dry enough to allow it to slough off. When the grout has hardened, it should be painted with iron waterproofing compound, or a similar preparation.

If cracks appear in prestressed concrete tanks, the problem should be referred to the erecting company for recommendations, even if the guarantee has expired or does not cover maintenance.

Semiannually, joints should be checked for leakage at the juncture of the floor and the walls, and for loose or missing filler, debris or trash. They should be cleaned and repaired as necessary.

Semiannually, the roof should be inspected for the condition of the covering. It should be made certain that roof hatches and other covers are locked, and that the screens on the overflow or at other locations are in place. They should be cleaned as necessary.

Where the tank rests on an earth embankment, it should be checked for erosion resulting from the lack of full sod or vegetation coverage, and for damage from burrowing animals, improper drainage, ponding water along the base, or leakage through the embankment or along the outlet piping. If leakage exists through the embankment, the tank should be drained and the bottom inspected for failure or cracks.

UNDERGROUND STORAGE. —If storage tanks are constructed below ground level, or are surrounded by an earth embankment, the semiannual inspection and repair include only the interior walls, roofs, appurtenances, and embankment. The inspection procedures and maintenance operations are the same as described above for ground level storage facilities. If the earth embankment, surrounding soil, or interior of the tank shows evidence of tank leakage, the earth may need to be excavated and repairs made on the walls.

ELEVATED STORAGE. Concrete storage tanks, which are elevated above ground, require the same inspection procedures and repairs as are outlined above, where applicable.

Steel Storage Tanks

Usually, outside contractors maintain and repair steel tanks. At times, though, you may have to perform various inspection and maintenance duties, such as those discussed in the following section.

GROUND LEVEL STORAGE.—Annually, after the winter season, steel storage tanks should be inspected for ice damage, water-tightness and structural conditions. Twice each year, the maintenance procedures set forth in the following paragraphs should be effected.

Tank walls (exterior and interior) and bottom (interior) should be inspected semiannually for rust corrosion, loose scale, leaky seams and rivets, and for the condition of the paint (both inside and out).

1. Replace rivets, or patch leaking areas, and follow by cleaning and painting.

2. Check painted surfaces for rust, corrosion, cracking peeling, alligatoring, chalking, fading, or complete loss of paint. Empty the tank and examine the interior paint as corrosion is more likely on the inside. If the interior needs painting, arrange to take the tank out of service. Paint the tank interior as often as the exterior (more often if the stored water is corrosive), unless the tank is equipped with cathodic protection.

A. Make certain that the paint used will protect the metal against corrosion. Consult the applicable guide specifications for paint selection and application methods.

B. Use only one new coat, if the previously applied coat is in fair condition. Bare spots of steel should be painted with a spot or patch coat before the finish coat is applied. If the condition of the old paint is bad, use a complete primer coat.

Semiannually, the roof and its appurtenances—screens on overflows, hatches, and manholes—as well as the condition of the paint, should be inspected. In this inspection, the following factors apply:

1. Make certain that the hatch covers and manholes are in place and locked, and that screens are in place to prevent the entrance of birds, insects, and animals.

2. If the spider rods under the roof have corroded, remove them, as they are needed only during erection.

3. Paint the roof, selecting the proper paint for the particular location.

As pointed out earlier, standpipes are, in effect, ground level storage tanks. Inspection and maintenance procedures for standpipes are the same as for ground level steel storage tanks.

UNDERGROUND STORAGE.—If steel storage tanks are constructed below ground level, or are surrounded by an earth embankment, the semiannual inspection and repair includes only the interior of the tank, the roof, and the appurtenances. The inspection and maintenance procedures are the same as given for ground storage steel tanks.

ELEVATED STORAGE.—In addition to the inspection and maintenance procedures set forth above for ground storage steel tanks, the following specific procedures apply to elevated storage steel tanks.

Semiannually, tower structures should be checked for rust and corrosion; loose, missing, bowed, bent or broken members; loose sway bracing; misalignment of tower legs; and evidence of unstableness. Ensure that the following items are covered:

1. Inspect the back surface of the lattice bars and anchor bolts, the inside of boxed channel columns, and pockets where batten-plate connections and column bases form pockets for collecting trash and water. Clean and paint these enclosures, and fill with concrete, as necessary, to shed water.

2. Check the bases and the base plates for evidence that water has collected at that point; if water if found, drill a 1 1/2-inch hole through the channel-boxed section to allow complete drainage. Then grout the base plate with a mixture of sand and asphalt to prevent water from running under the plates. Taper the grout from the top edge of the plate to the pier.

3. Check the sway bracing and tighten the turnbuckles, if necessary. Examine under clevis pins and rod loops where corrosion may be greatest. Drill holes in the balcony floor to eliminate standing water.

In addition to general roof inspection and repair, as previously described for ground storage steel tanks, obstruction and navigation lights should be inspected and relamped, if necessary. The following items also should be covered:

1. Check the operation of all other lights; check hoods, shields and receptacle fittings; look for missing or damaged parts. Repair or replace parts as necessary.
2. Check lightning rods, terminals, cables, and ground connections.

In cold climates, potable water storage tanks, with small riser pipes, and elevated storage tanks, for fire protection only, usually have heating equipment to prevent freezing in periods of severe low temperature. Ensure that the following items are covered:

1. Annually, two months before the freezing season, inspect the riser for deterioration of the frost covering. Seal any openings to minimize heat loss. Also, check the heating system to ensure proper operation during the ensuing cold season.
2. Annually, one month before the freezing season, operate the heating system for 8 hours to check all elements under operating conditions.

CATHODIC PROTECTION EQUIPMENT.—Only impressed-current cathodic protection systems are used for protecting steel water storage tanks against corrosion. This system of protection may be applied to all types of steel water tanks—ground level, standpipe, underground, and elevated tanks. Refer to the material presented earlier in this chapter for a discussion of inspection and maintenance procedures for impressed-current systems. In addition, the following procedures apply.
Annually:

1. Note and record the current flow during the operation. If the current does not flow, check the fuses; electrodes which make contact with the tank; ground-wire connection to the tank; and the immersion of electrodes. If the equipment is operating at voltages or amperages above those listed on the nameplate, the rectifier may be damaged. CAUTION: Make certain that the connections to the rectifier are not reversed; reversed connections will result in tank damage.
2. Check the operating record to determine if the electrodes are immersed at all times, or almost all the time. If the electrodes are not immersed, there will be no damage to the unit; however, protection is not provided when the electrodes are not immersed.
3. Check the anode condition and replace the anodes as necessary. Also, check the current flow; if it has diminished since the previous inspection, the anode probably needs to be renewed.

4. In freezing climates, protect electrodes from ice which may tear them from their hangings or damage them. If ice formation is severe, turn off the current, remove the electrodes, store them until the freezing season is past and then reinstall them.

5. Test the effectiveness of the cathodic protection system in one of two ways.

   A. Scrape and polish a spot on the tank wall at a point always immersed. At quarterly intervals, lower the water and inspect the spot; if protection is adequate, the spot will remain uncorroded.

   B. Suspend two polished mild-steel test plates in the tank at an elevation where they will always be immersed (use No. 6 galvanized steel wire). Ground one plate to the tank wall, but have the other plate insulated from the tank. The extent of corrosion on the grounded plate will approximate the corrosion of the protected tank; the extent of corrosion on the other plate is a measure of the corrosion that would occur if the tank were not protected.

Pneumatic Tanks

As pneumatic tanks are usually found in smaller installations, they may be too small for interior inspection, except for observations through a removable hand plate. The size, therefore, indicates the inspection procedures to be followed.

1. Quarterly, inspect the air pump and motor to make certain both are operating properly. Check the operating record to determine the time cycle of air pump operation. If the records show a decreasing time cycle, check for possible air line leaks.
2. Quarterly, check valve operations; particularly, check the pressure relief valve. Repair or replace as necessary.
3. Annually, check the tank for signs of corrosion, both internally and externally. If

corrosion products are apparent, take the following action:

A. If the tank is large enough to permit the entry of personnel, paint the inside with corrosion resistant paint, or line it with cement. If the tank is too small to permit entry, consider the possibility of changes in operation or in chemical treatment to reduce corrosiveness of water. Corrosion effects are most likely in areas alternately exposed to air and water.

Table 11-8. — Maintenance Procedures for Storage Facilities

Inspection	Action	Frequency
Foundations, concrete	Check for settlement, cracks, spalling and exposed reinforcing; repair as necessary with 1 part cement to 1 part sand.	SA
Foundations, wood	Check wood foundations and pads for checked, split, rotted or termite infected members; also check for direct contact of untreated wood with soil; repair or eliminate undesirable conditions as necessary.	SA
Concrete tanks (ground level storage).		
Walls	Check exterior for seepage; mark spots.	SA
	Check exterior and interior for cracks, leaks, spalling, etc.	A (Spring)
	Remove loose, scaly, or crumbly concrete; patch with rich cement grout; paint grout with iron waterproofing compound.	A
	Chip out cracks, repair with cement slurry.	A
	For cracks in prestressed tanks, consult designing and/or erecting company.	A
Expansion joints	Check for leakage; check for missing filter; clean and repair as necessary.	SA
Roofs	Check condition; check hatches; check screens on openings.	SA
Earth embankments	Check for erosion, burrowing animals, improper drainage and leakage through embankment; repair as necessary; if leakage through embankment exists, drain tank and look for cracks in tank walls or bottom.	SA
Concrete tanks (underground storage).	Check interior walls, roof, appurtenances and embankment; if leakage is evident, excavate and repair walls.	SA

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Table 11-8.—Maintenance Procedures for Storage Facilities—Continued

	Action	Frequency
Concrete tanks (elevated storage).	Check and repair	SA or A . . . . . .
Steel tanks (ground level storage).	Check for ice damage in Spring; repair as necessary.	A . . . .
Walls and bottom	Examine exterior and interior for rust, corrosion products, loose scale, leaky seams, and rivets and for condition of paint.	SA. . . . .
	Replace rivets or patch leaking areas, as necessary.	V. . . . .
	Check painted surfaces for deterioration; paint as necessary.	SA. . . . .
Roofs.	Check condition, hatches, screens, manholes and paint; lock hatches; remove spider rods if corroded; repair, replace or paint as necessary.	SA. . . . .
Steel tanks (standpipes).	Follow instructions for ground level storage given earlier in this chapter.	SA. . . . .
Steel tanks (underground storage)	Check tank interior, roof and appurtenances; follow instruction given earlier in this chapter.	SA. . . . .
Steel tanks (elevated storage)	For general procedures follow instructions given earlier in this chapter. For specific procedures see following paragraphs.	SA. . . . .
Tanks.	Follow instructions given earlier in this chapter.	SA. . . . .
Tower structures.	Check for corrosion; loose, missing, bowed, bent or broken members; loose sway bracing; misalignment of tower legs; evidence of instability; repair as necessary.	SA. . . . .
	Check surface of lattice bars, anchor bolts, boxed channel columns and pockets where water or trash collects; clean, repair, provide drainage or fill pockets; paints as necessary.	SA. . . . .
Roofs.	Follow the general instructions given earlier in this chapter.	SA. . . . .
	Check obstruction and navigation lights, hoods, shields, receptable and fittings for missing or damaged parts, or inoperation; also check lightning rods, terminals, cables and ground connections; repair, replace or renew; paint as necessary.	SA. . . . .

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Table 11-8. — Maintenance Procedures for Storage Facilities — Continued

Inspection	Action	Frequency
Risers and heating systems.	Two months before freezing weather, check riser pipe insulation and repair as necessary; also check heating system operation.	A. . . . .
	One month before freezing weather, operate heating system for eight hours; repair or adjust defective parts.	A. . . . .
Cathodic protection	In additon to the following instructions, observe those given earlier in this discussion regarding cathodic protection of sedimentation tank equipment.	A or V . . . .
	Check flow of current; if absent, check fuses, electrodes, ground wire connections and immersion of electrodes; adjust or repair as necessary; if current flow or amperage is above desired level, adjust as necessary; make certain that connections to rectifier are not reversed.	V. . . . .
	Check operating records to make sure that electrodes are immersed at all times.	V. . . . .
	Check anode condition; replace as necessary.	V. . . . .
	In freezing climates, protect electrodes against ice damage, or remove and store for winter season.	V. . . . .
Pneumatic tanks	Inspect air pump and motor; check operating record of time cycle; check for air leaks, if time cycle is too short; check valve operations, particularly pressure relief valves.	Q. . . . .
	Check tank for signs of corrosion; take steps necessary to eliminate corrosion or protect against it.	A. . . . .
Appurtenances	Check ladders, walkways, guardrails, handrails, stairways and risers for rust, corrosion, poor anchorage, missing pieces, general deterioration or damage; replace or repair parts as necessary.	SA. . . . .
Miscellaneous appurtenances.	Check all electrical connections and conduits leading to tanks; make any repairs or adjustments necessary.	SA. . . . .
Grounds	Check for accumulations of debris, trash and foliage; clean the area.	SA. . . . .

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8. Paint the exterior as needed.

Appurtenances

Semiannually, ladders, walkways, guardrails, handrails, stairways, and risers should be inspected for rust, corrosion, poor anchorage, loose or missing pieces, or other deterioration or damage.

1. Be sure to check ladders inside as well as outside of the tank. Replace worn, corroded or missing parts; check for deteriorated lugs and rungs as necessary; and, make other repairs needed to ensure safety for the operators. Check revolving ladders on the roof for the condition of connection at the final hook-ups.
2. Ensure that bolts, screws, rivets, and other connections are tight.
3. Inspect the altitude valve vault's condition, and the valves for proper operation. Repair, clean, and paint all equipment when necessary.
4. Check the water level indicator for improper operating conditions, and repair when necessary.
5. Inspect the cathodic protection equipment and repair when necessary (follow instructions given in previous portions of this chapter).
6. At semiannual intervals, check the electrical connections to lights, cathodic protection, etc., for breaks in the conduit. Remove the conduit inspection plates and examine the internal connections for tightness and adequacy; also check relays for weak springs, worn or pitted contacts and defective operation. Repair and eliminate all undesirable conditions.

Grounds

At semiannual intervals, remove all accumulations of dirt, trash, debris, and excess foliage on the area surrounding the storage tank.

Maintenance Procedure Schedule

The maintenance operation frequency and schedule of inspections for storage facilities are presented in table 11-8.

CHAPTER 12

SEWAGE TREATMENT AND DISPOSAL

Proper sewage treatment and disposal are of major importance to the health and welfare of all personnel. As in the case of water purification here is a service that is taken for granted. It is of great significance to the welfare of the group and must be accomplished in an effective manner.

Briefly defined, SEWAGE IS THE WASTE MATERIAL THAT FLOWS THROUGH A SANITARY SEWER SYSTEM. It consists mainly of water-borne waste matter discharged from water closets, showers and the kitchen. It may also contain laundry wastes and other floating solids such as paper, matches, grease, and debris.

Sewage is a liquid that usually has animal, vegetable, and mineral matter in suspension and in solution. It also contains a vast number of bacteria, most of which are harmless. However, as some of the bacteria may have been discharged by victims or carriers of infectious diseases, they are dangerous. While sewage has a number of elements in its makeup, the biggest by far is water. By weight, water is about 99.9 percent of the total.

Sewage is collected and treated primarily to prevent spreading of communicable diseases. It is also collected and treated to prevent contamination of water supply and damage to property; to safeguard bathing beaches, fish, and livestock; and, in general, to prevent conditions that would be offensive to sight and smell.

To find out how well the treatment facility is performing in the prevention of spreading diseases, detailed reports of operation are necessary. Daily records show the operator what his facility is doing, while monthly summaries are used for comparison of current and past performances. Accumulated records are the best for evaluating a given process or method of operation.

This chapter discusses methods used in the treatment and disposal of sewage at sewage treatment facilities and at installations where common sewers are not available. Information also is provided on environmental pollution control, with special attention being focused on topics relating to water pollution.

SEWAGE COLLECTION SYSTEMS

Before sewage can be treated properly, it must be collected at one location. This is accomplished by a sewage collection system, which consists of all facilities for the collection, transportation, and pumping of domestic sewage. All drainage is excluded to avoid constructing large sewers and treating large volumes of sewage during storms. Figure 12-1 will give you an idea of the layout of a sewerage system. The collection systems include the following:

HOUSE SEWER. Pipe connecting the sanitary plumbing facilities of a single building to a common sewer.

LATERAL SEWER. Line connecting to a branch or other sewer and having no other common sewer tributary to it.

BRANCH SEWER. Sewer serving a relatively small area.

MAIN SEWER. Sewer to which two or more branches are connected.

TRUNK SEWER. Sewer with many branches which provides outlet for a large area.

FORCE MAIN. Pipe carrying sewage under pressure from a pumping station.

INTERCEPTOR SEWER. Main line intercepting a number of main sewers and connecting to a treatment facility or disposal point.

INVERTED SIPHON. Sewer depressed below the hydraulic grade line and flowing full at all times.

PUMPING STATION. Equipment for lifting sewage to a higher elevation.

OUTFALL SEWER. Line leading from a treatment plant or collecting system to the final disposal point.

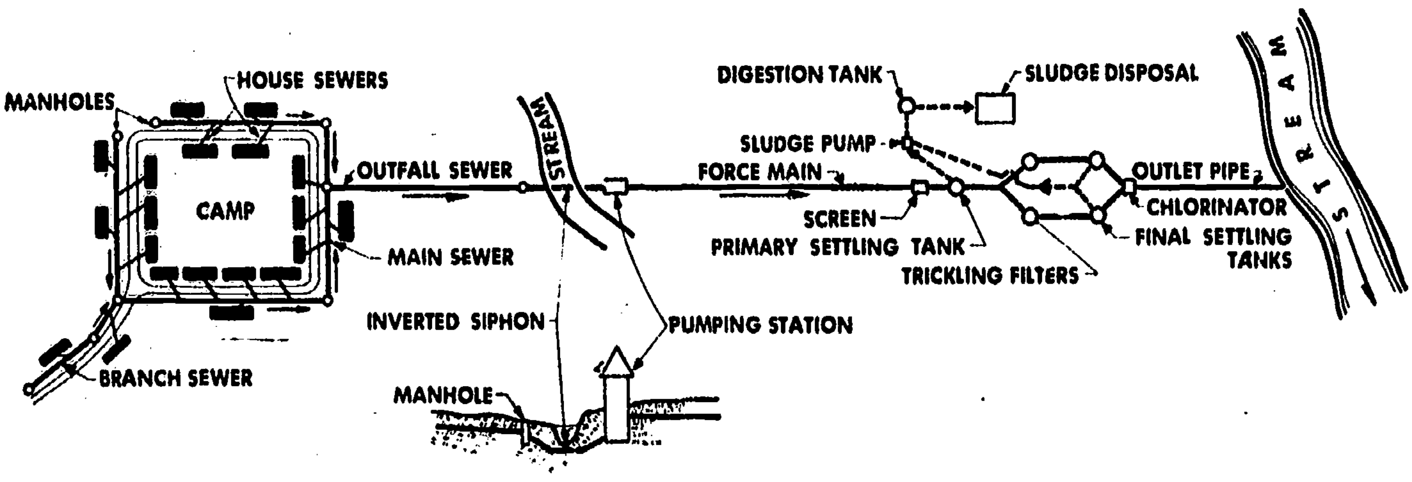

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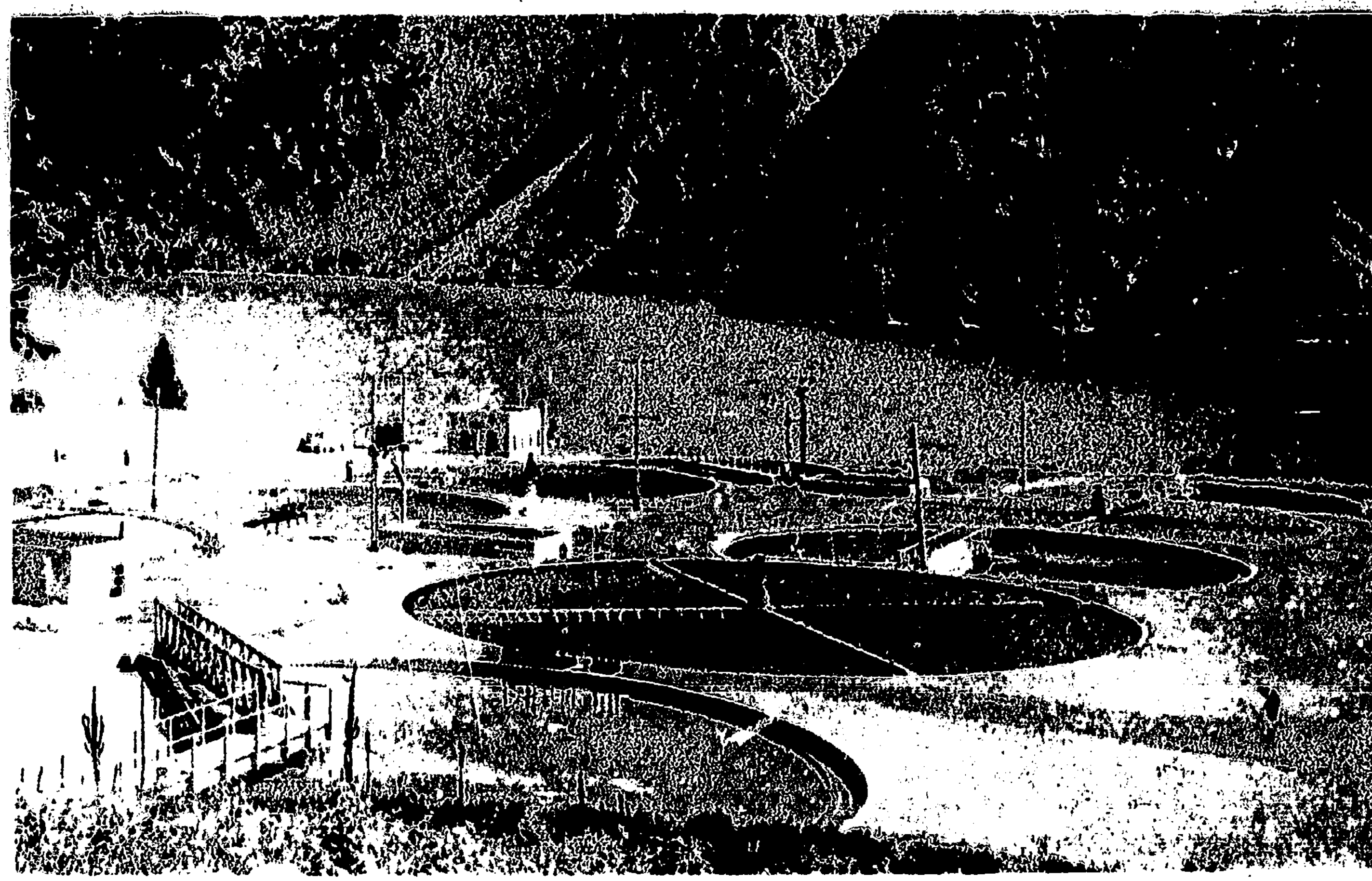
Figure 12-1. — Layout of a sewerage system.



54.105B

Figure 12-2. —A sewage disposal facility.

SEWAGE TREATMENT FACILITY

At the sewage treatment facility, the liquid and the solids receive several different processings. The equipment and treatment may vary according to local needs. Figure 12-2 will give you an idea of what the sewage disposal facility may look like at an activity.

One of the treatment processes, known as PRIMARY treatment, is used to remove part of the suspended and floating solids. This is done by passing the sewage through screens or grinders. Because the fine suspended solids are not completely removed, further screening by fine screens may be next. Or the sewage may go to sedimentation tanks. Here the solids settle to the bottom of the tank.

The solids, known as SLUDGE, that have settled to the bottom of the sedimentation tank are placed in separate digestion tanks. Here the sludge is reduced to inert odorless solids. After the sludge is digested, it is placed on sand beds for drying; or it may be dried by mechanical means. The dried sludge may be disposed of by using it as fertilizer or as fill for low ground.

In many localities, primary treatment is the only treatment given before the sewage goes out for disposal. In these cases, the plant effluent is sent into a body of water where nature helps purify it. The primary treatment has made it safe enough, and dilution takes care of the rest. However, in some localities it is desirable or necessary that the sewage receive SECONDARY treatment. The process of secondary treatment aims at removing more of the finely suspended matter and also at mixing the sewage liquid less objectionable. Mixing oxygen with the sewage is the chief feature of secondary treatment. It makes the sewage safer for disposal, but not necessarily 100 percent pure.

One of the secondary processes consists of passing the sludge and liquid through beds of stone known as TRICKLING FILTERS. Other methods of oxidizing include contact aeration and the activated sludge process. The first method mixes oxygen and sludge by having compressed air come from perforated pipes under contact plates in the tanks. The second method mixes sewage that has already received primary settling with sludge that has started to decompose and which is known as activated sludge. This mixture results in a mixed liquor that is treated with compressed air through diffuser plates or is sprayed by mechanical aerators. After this, the liquor may go to a secondary settling tank for more clarification and then for disposal without further treatment. Another secondary treatment method is subsurface irrigation. This method of disposing of the effluent uses subsurface tile fields.

You may find chlorination used in the same general manner as at a water treatment plant. It is used for disinfection of the plant effluents, odor control, and to facilitate the various treatment processes. At treatment facilities, you will also find laboratories used to analyze samples of sewage by performing various tests.

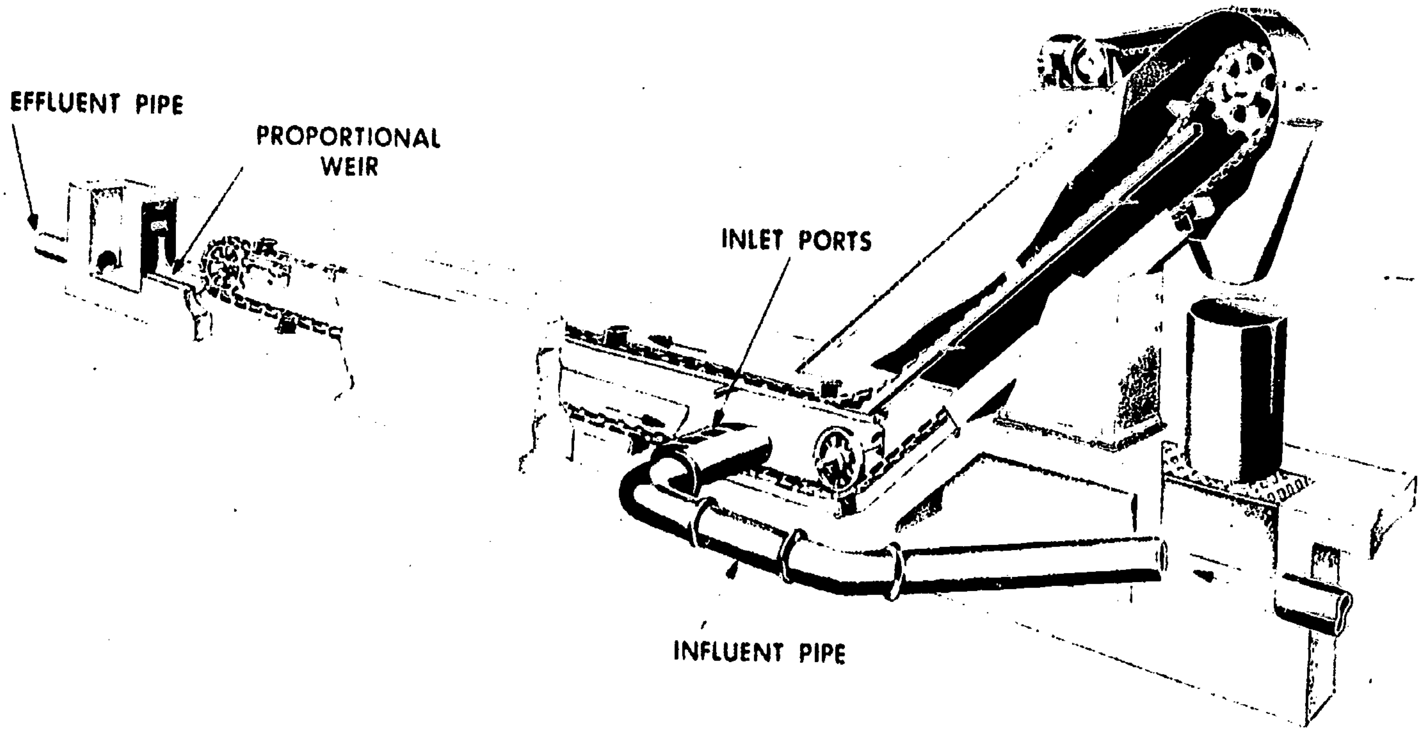
GRIT REMOVAL

One of the common processes found in most treatment facilities is grit removal. This process is just what it is called. The sewage reaches a large channel or long tank called the GRIT CHAMBER at the influent (incoming) end of the facility (see fig. 12-3). This chamber is specially designed to slow down the flow so that the heavier solids settle to the bottom. Such items as sand, gravel, cinders, and coffee grounds are stopped here. This process of removing such coarse matter helps avoid excessive wear and clogging of the plant's pumps, sludge collectors, and other equipment.

The grit, except for the very fine particles, will settle quickly when the flow of the water is reduced to about 1 foot per second (fps). Grit channels usually have proportional weirs, Parshall flumes, or other devices for automatically maintaining the proper velocity; observe that a porportional weir is used in the grit chamber in figure 12-3. In the absence of such devices, regulation is accomplished by stop gates periodically adjusted for proper velocity of 1 fps over the normal daily flow variation.

If the flow gets too slow, material which still contains living organisms will also settle with the grit. This will decompose and produce bad odors. If more than 15 percent of the settled grit is organic material, there is need for a change in operating the chamber or perhaps for a new chamber of different design.

Usually two or more channels, used alternately, are provided for manually cleaned chambers to allow drainage and removal of grit. Channels are designed to provide a lower compartment for the accumulated grit and an upper compartment for the flowing sewage. The two compartments have no physical separation. Grit depth may be gauged by a graduated pole. Grit



54.106

Figure 12-3.—Grit chamber.

should be removed whenever 50 to 60 percent of the lower compartment is filled and immediately after every heavy storm. The following method of cleaning may be modified to suit the local conditions:

1. Close the end gates to the channel to be cleaned and open the other channel.

2. Drain by gravity or a portable pump if no drain is provided. Water is discharged to primary settling tanks.

3. While draining, agitate and flush the material with water to remove organic solids and move sand to the end of the channel opposite the drain.

4. When the grit has been drained, remove it with shovels and buckets.

Mechanical grit-removal equipment is usually operated intermittently except at larger plants where operation is frequent enough to prevent overloading. The operation should be continuous during excessive flows. Grit from this type of equipment is relatively free of objectionable matter and can be used for covering screenings or filling poorly drained areas. When organic matter is present, burial or incineration is necessary.

Each manufacturer has instructions for the operation, lubrication, and maintenance of its grit-removal equipment. Study the manufacturer's instructions for the equipment concerned and see that they are carefully followed in your work.

SCREENS AND GRINDERS

Sewage plants and pumping stations are equipped with bar screens and comminutors, or other types of grinders. The function of these devices is to eliminate large objects, such as rags and wood, which may clog pumps, piping, or other equipment. In some cases, fine screens with openings of 1/4-inch or less are used to remove additional suspended solids.

Bar Screens

Bar screens have a grid of steel bars spaced on centers varying from 3/4-inch to 2 1/2

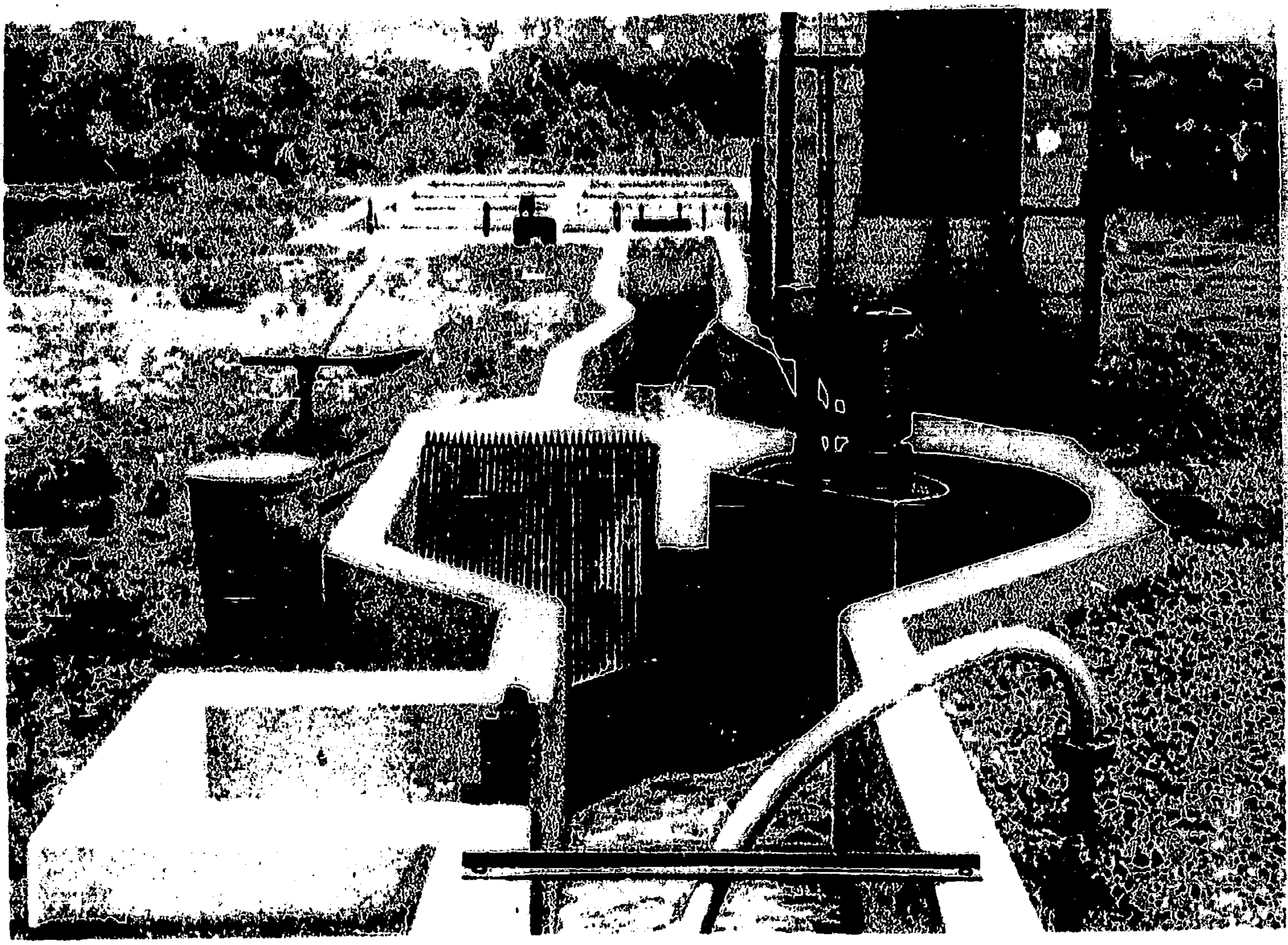


Figure 12-4. — Bar screen and comminutor. 54.107

inches and installed at an angle in the direction of the flow in an enlarged portion of the influent channel. These screens may be cleaned manually with a rake by pulling the screenings up the bar and depositing them on a draining platform. Figure 12-4 shows a comminutor and a manually cleaned bar screen.

Mechanical equipment is sometimes used to clean the screens. This equipment is operated intermittently by a time clock or a float switch actuated by increased head loss through the screen. This change in head loss is caused by the accumulation of screenings on the bars. The screenings are raked upward by the mechanism and dropped into a receptacle, grinder, or shredder.

When the manual method of cleaning is used, ensure that the bar screen is kept clear by raking at frequent intervals. Neglecting to clean screens may cause sewage to back up in the influent pipe and overflow the screen chamber. Clogged bar screens cause material to settle in the influent line, where it becomes septic and odorous. This septic material is suddenly washed to the treatment facility when the screen is cleared. This is objectionable because best treatment facility performance is secured when the sewage is received fresh and in uniform amounts. Screens should be cleaned as follows:

1. Rake screenings onto the drainage platform. As soon as most of the water has drained, place screenings in some covered receptacle, such as a 10-gallon garbage can with small holes in the bottom to drain off excess water. Place the cover on the can immediately and clean the platform with water from a hose. Treat screenings from mechanical rakes similarly.

2. Flush the screen chamber and screen at least once during each shift to remove grease from walls and bars and accumulated solids from the area ahead of the screen.

3. Clean fine screens by scrubbing or brushing, preferably with water under pressure from a hose. Remove grease on tools, screens, or other equipment with soapy water.

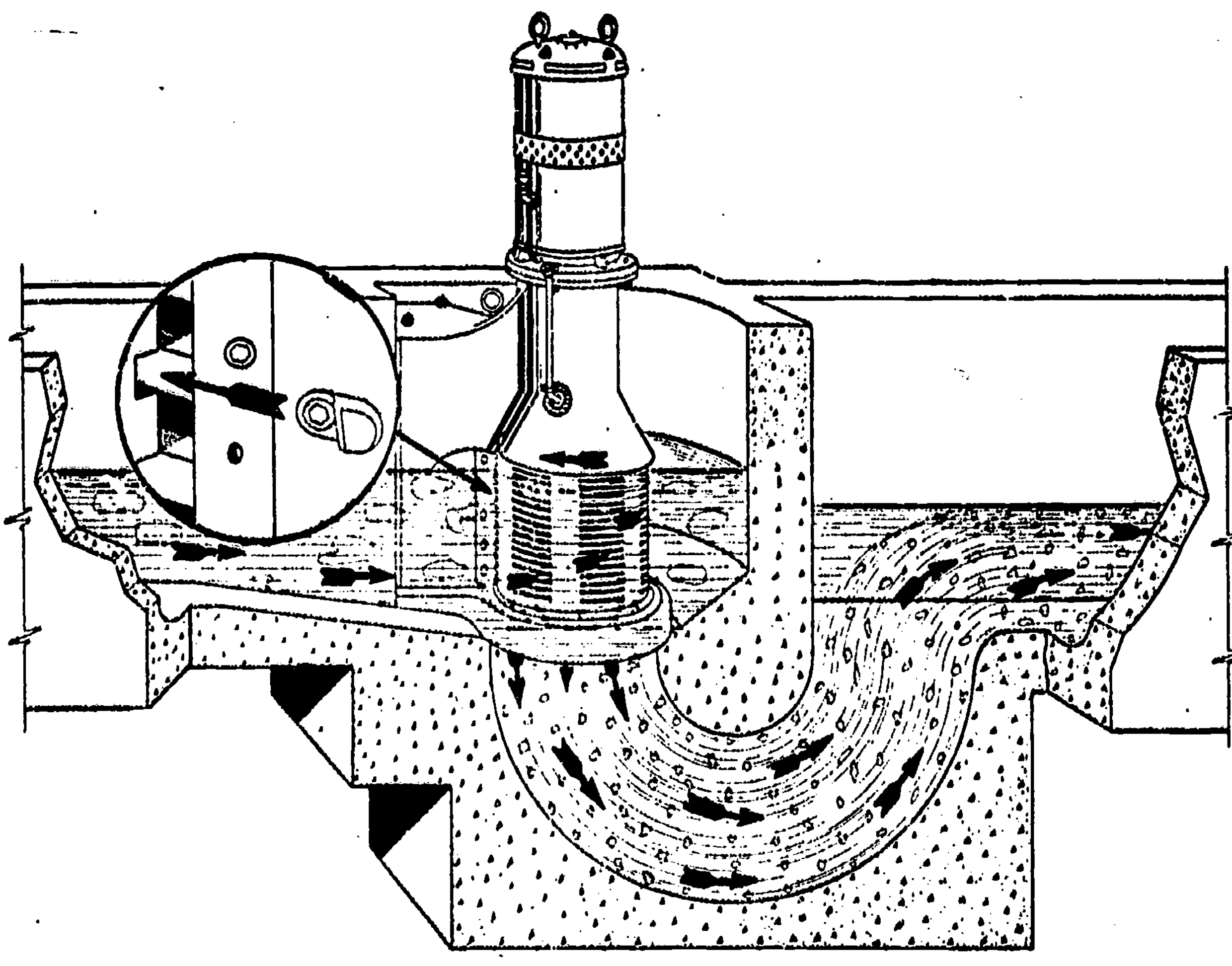
Screenings from bar or other coarse screens contain putrescible material and should be disposed of in a sanitary manner. Where equipment is available, GRINDING is the best method of disposal. Accumulated screenings are ground once or twice during each operating shift. Manufacturer's instructions for operating and cleaning the machines must be carefully followed. The grinding teeth should be resharpened before wear becomes excessive.

Where INCINERATORS or SANITARY FILLS are available, screenings may be disposed of with the garbage or refuse. Daily collections are necessary to prevent an odor nuisance or flies. Under no circumstances may screenings be disposed of with garbage that is used for hog feeding or by plowing under in cultivated land.

Disposal by BURIAL by the plant operator may be necessary if other means are not available. The method used is similar to that for garbage disposal by sanitary fill.

Grinders

Some mechanical grinders use swing hammers to grind the solids into a pulp while rocks, iron, and other hard materials are deposited in a trap. Others use a high-speed rotor fitted with tool-steel teeth that shred



54.388

Figure 12-5. —Sectional drawing of comminutor.

the material as it passes between them. The ground material is washed back into the raw sewage at a point beyond the screen.

Comminutors

The comminutor — another type of grinder — has a vertical drum that is revolved by an electric motor. Cutting knives, located on the drum, shred solids that are too large to pass through openings between the knives. Sewage flows through these openings, forcing the solids against the knives again and again until they are cut to proper size. The comminutor is installed in the inlet channel to the plant or pump station and is used generally in conjunction with a bar screen. The latter is available for use when the comminutor is being repaired. Figure 12-5 shows a sectional drawing of a comminutor in place.

The comminutor should be cleaned with a Navy-approved cleaning solvent, such as Kem-Ko ND-25, to remove grease and keep the comminutor clear. An accumulation of grease can result in a stoppage of the flow of sewage throughout the sewer system.

SETTLING TANKS

Settling tanks may be classified as to purpose, in which case you have primary tanks for treating raw or screened sewage, intermediate tanks located between two stages of biological treatment, and final tanks for the last stage of settling. Settling tanks may also be classified according to the method of sludge removal. This classification includes hopper-bottom tanks and mechanical sludge-collection tanks. Those designed for mechanical sludge removal may be rectangular, circular, or square.

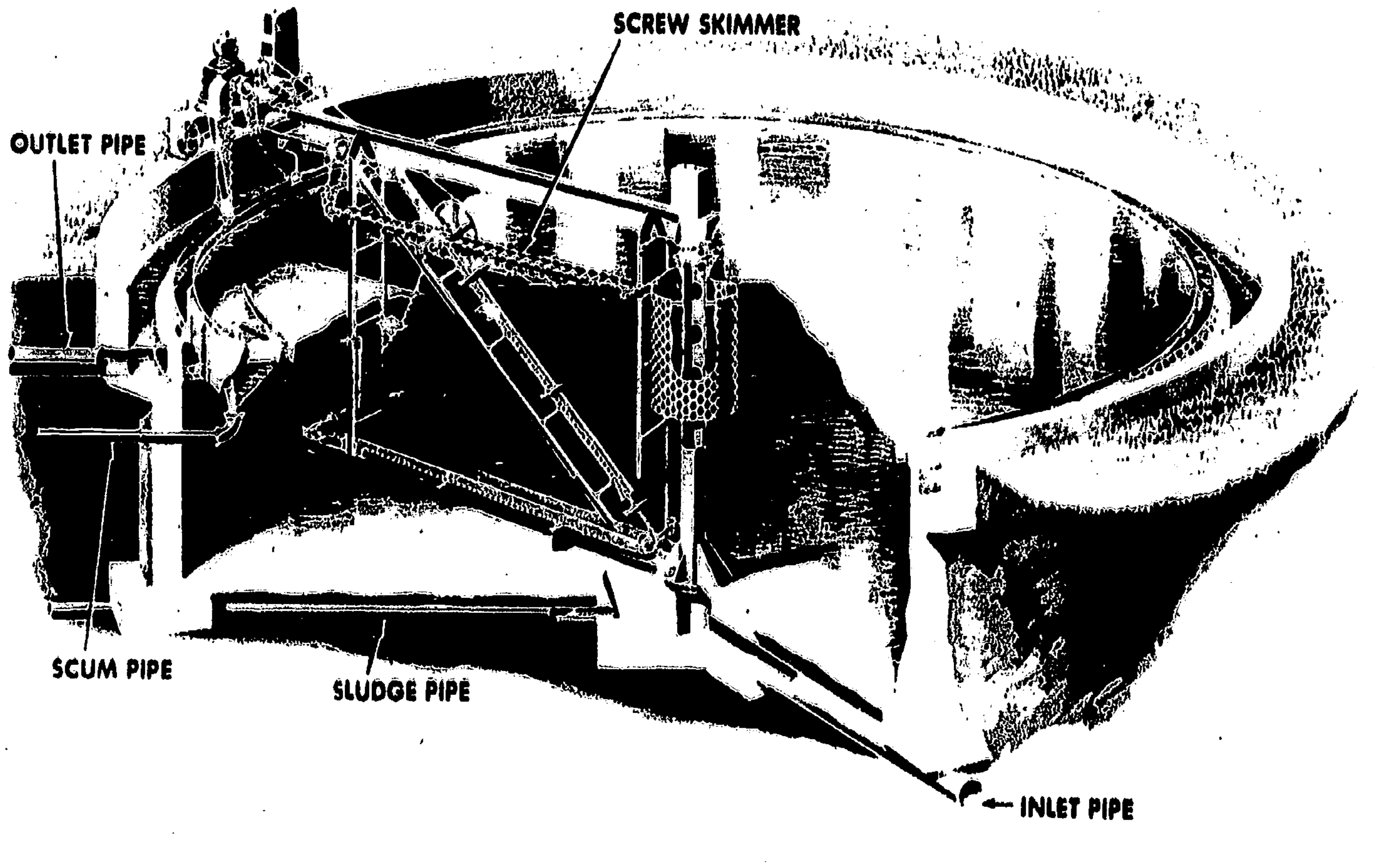


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Figure 12-6. — Circular settling tank.

RECTANGULAR-TYPE TANKS have chain conveyors which sweep the sludge particles accumulated on the bottom toward the sludge hoppers at the influent end. On the primary tank, the conveyer sweeps the entire surface of the tank, forcing the scum directly to the draw-off point in front of the effluent baffle. Sludge hoppers are emptied by gravity or by pumping while the tank remains in operation.

Figure 12-6 is a cut-in view of a circular tank, showing a type of sludge collector mechanism. The influent comes through a centrally located, inverted siphon surrounded by a submerged diffuser, which introduces the feed quietly well below the surface, distributing it evenly to all parts of the tank. The radial flow through the tank reaches minimum velocity at the overflow point across a continuous peripheral weir. Blades attached to rotating arms scrape the sludge from the floor of the tank to a small centrally located hopper. Sludge is removed through a sludge pipe either by gravity or by pumping.

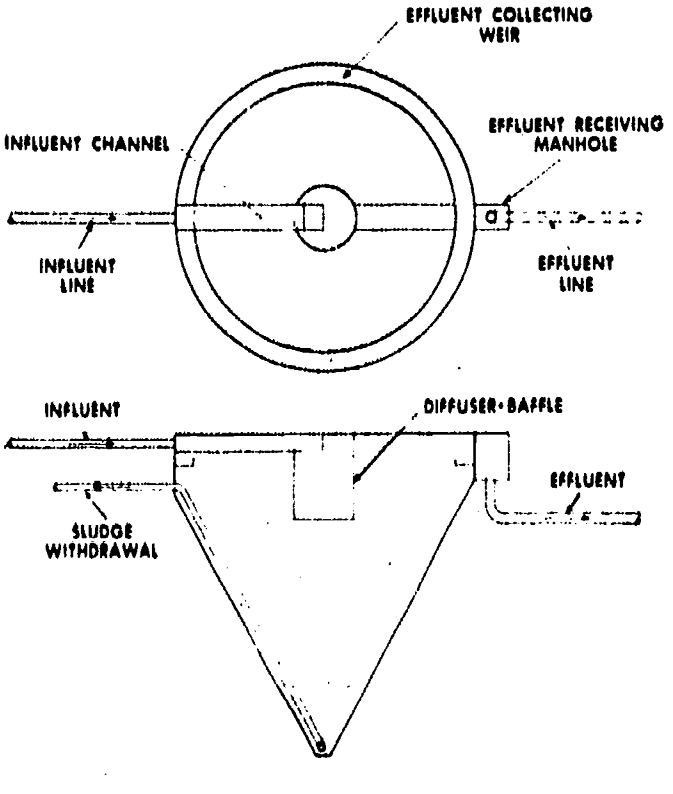

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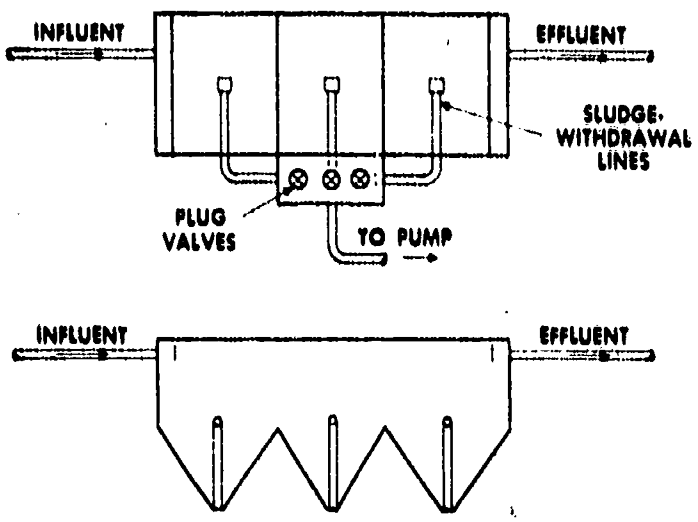
Figure 12-7. —Single conical hopper settling tank.



54.271
Figure 12-8. —Multiple-hopper settling tank.

If a sludge-collecting mechanism is not available, a hopper bottom tank is used. Hoppers are well suited to smaller installations. The single conical hopper and the multiple-hopper type settling tanks are illustrated in figures 12-7 and 12-8, respectively. The sludge is accumulated in the hopper sections and is removed through withdrawal pipes.

Detention Periods in Settling Tanks

The normal detention period of primary- and secondary-settling tanks should be 2 1/2 hours for average daily flow, except for activated-sludge-plant primary tanks, which should be 1 1/2 hours. Excessive detention may cause septic sewage, produce odors, and increase the load on secondary-treatment units. Where duplicate units are used long detention periods are avoided by removing one or more tanks from service during continued low flows or by recirculating effluent from secondary units through the primary tank. When removal of solids by settling tanks is far below normal (50 to 70 percent suspended solids), the cause should be determined; good operators should constantly be on the alert for ways to improve operation.

Operation of Settling Tanks

Good housekeeping practices are essential to prevent odors, flies, and unsightly appearance. Floating solids passing out with the effluent may clog the filtering equipment; grease may cause ponding of filter media.

Floating material must be removed once each shift, or more often if it is present in large quantities. Some mechanical skimmers automatically remove material to a sump for disposal; other tanks have a manually operated skimming pipe. However, a hand skimming tool should always be used to facilitate entrance of skimmings into the pipe or trough. Where skimmings are pumped to the digester, a minimum of sewage and wash water should go with it to prevent upsetting the digester operation. If large quantities of fairly dry skimmings tend to upset digestion, they should be collected in a covered can, with openings for draining excess water, and hauled to a sanitary fill or incinerator. The can must not be placed where drainage becomes a nuisance. If a fill is not available, skimmings are drawn to a trench and covered with at least 2 feet of earth. A spray of water under pressure, directed against floating material, frequently settles floating material.

Ensure that sidewalls of chemicals, baffles, weirs, launders, and tanks are kept clean of grease and other solids by hosing, scraping, or brushing once each day, or more often if necessary. Dead ends and corners are brushed at least once each shift, and fine sand and gravel are removed for burial or used as fill. Decks and walks are hosed at least once each day. Where pressure is not available for hosing, a secondary effluent may be used with a portable pump, pressure system, or other pumping equipment.

If grit appears in channels or hoppers, the grit chamber operation should be checked. If the unit has no grit chamber, one should be installed if necessary. However, because grit is a sign of breaks in the sewer system or storm water connections, the system should be checked thoroughly before a grit chamber is constructed.

Sludge Withdrawal

Proper sludge withdrawal is important to settling efficiency. The solids content of the sludge should be as high as possible. This means a slow rate of withdrawal and the stopping of the withdrawal when the sludge becomes thin. The water volume in the digester must be reduced wherever possible, because this volume directly affects the digester operation. A decrease in solids content causes a larger volume of sludge to be heated, a greater volume of digester supernatant to be returned, and reduction of effective capacity. For example, 3 points of dry solids pumped as a 3 percent sludge puts into the digester 97 pounds, or about 11.7 gallons of water; the same dry solids pumped as a 6 percent sludge introduces 47 pounds, or about 5.65 gallons of water, about half as much. Sludge must be drawn slowly (50 to 60 gpm or less) to avoid pulling light sludge and sewage to the intake; it is sampled during the drawing to determine the consistency and obtain a composite sample. A quick-opening 2-inch valve must be provided for sampling if other means are not available.

Hopper-bottom tanks require more care in drawing sludge because of the larger number of hoppers. Sludge from the hoppers at the effluent end normally has a low solids content, but it must be removed to prevent carrying over with the effluent. Hoppers are squeegeed several times each week to remove adhering solids.

The interval between removals is regulated by the sewage load and weather conditions. Shorter intervals are required during high flows of strong sewage and during warm weather. If sludge rises from the hoppers, the removal is incomplete or too infrequent. Primary sludge is removed normally from the settling tank three to four times each 24 hours. Sludge collected in settling tanks following standard trickling filters is drawn at least once each day, except during filter sloughing, when more frequent withdrawal is advisable. Good judgment is necessary to obtain a balance between a high solids concentration and a clean tank bottom, especially where light sludge from secondary processes is returned to the primary tank for resettling.

Mechanical sludge collectors in circular tanks and all settling tanks for activated sludge must be operated continuously. Intermittent operation of circular-tank mechanisms causes solids to accumulate on the tank floor, placing a large starting load on the mechanism. Continuous operation provides greater sludge compaction. Sludge collectors in rectangular tanks are not usually operated continuously, although it may be done, especially when the sewage is strong and the rate of flow is high. The mechanism should be normally started from 1 to 2 hours before pumping, the tank length governing the length of this period, somewhat. At least two complete runs for the length of the tank are desirable. The tank bottom must be well cleaned and old sludge must be completely

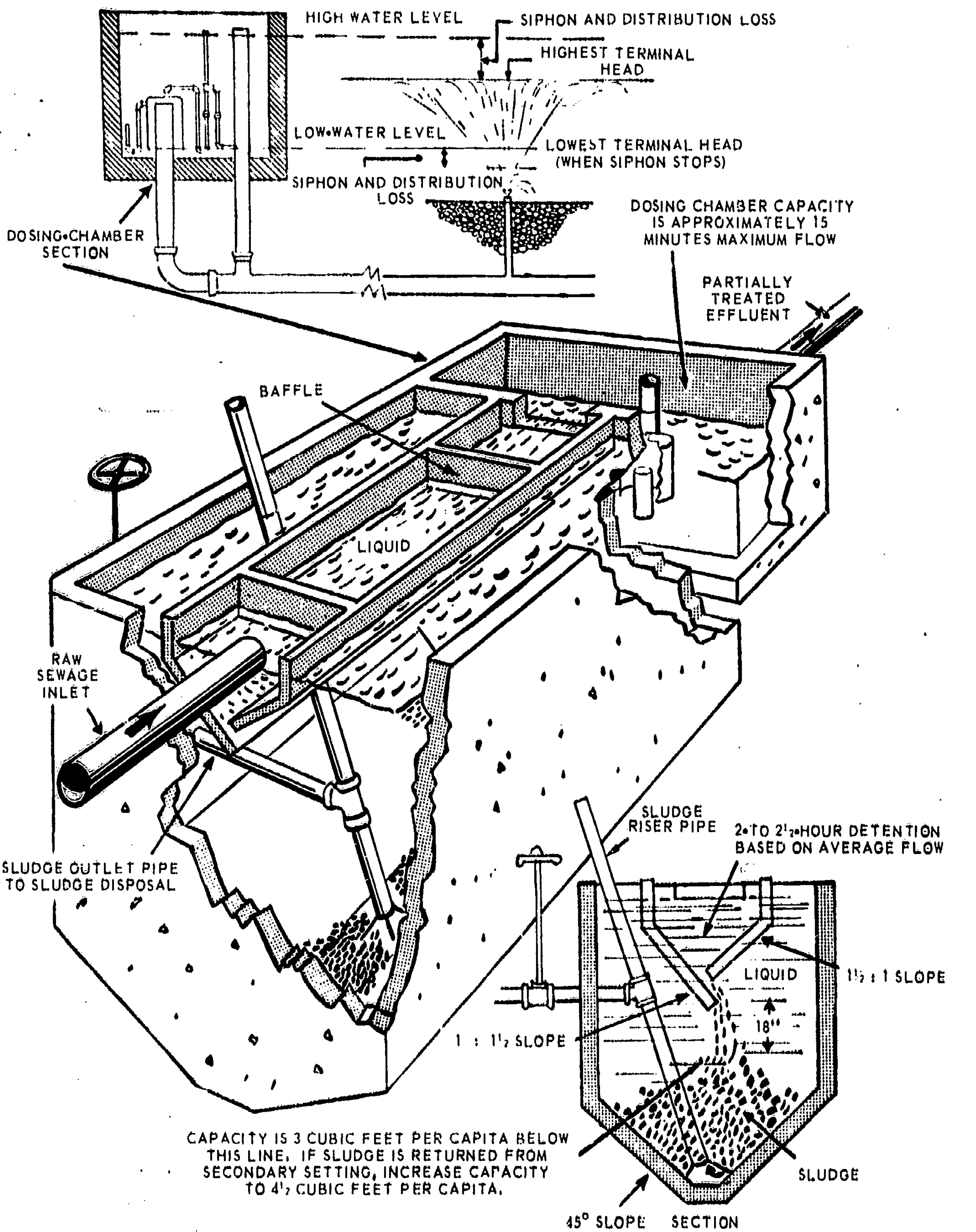


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Figure 12-9.—Imhoff tank.

removed to the hoppers. Rising gas bubbles and sludge along the tank indicate incomplete cleaning or too long a period between operations. Hoppers in rectangular tanks should not be filled more than 6 inches from the top. When sludge is being withdrawn, 2 feet of sludge blanket may be left in the hopper. Where there are two or more hoppers, only one should be drawn at a time.

IMHOFF TANKS

The imhoff tank (one of the dual-compartment tanks) is a two-story structure with an upper (flowing-through) compartment of primary settling and a lower one for sludge digestion. (See fig. 12-9.) Solids that settle from the sewage pass through a slot in the hopper-bottom of the flowing-through compartment. Sludge digestion produces gas, which passes upward (being diverted at the slot) to gas vents beside the settling compartment. This permits settling unhindered by rising gas and is a more efficient form of settling than that in septic tanks. In this type of facility, the sludge compartment is not heated. Although provision is sometimes made for gas collection, gas is generally released into the atmosphere. Digested sludge is withdrawn, either by gravity or by pumping, from the bottom of the sludge compartment through a sludge line. Imhoff tanks usually provide a 2-hour detention for average flow in the settling compartment and a sludge-holding capacity of 3 to 4.5 cubic feet per capita.

PRIMARY SETTLING COMPARTMENTS

Proper distribution of the influent flow to the settling compartments is essential for efficient settling. Where two or more units are installed, flow is distributed between the units by adjustment of the influent gates. Properly placed dividing lines of bricks or triangluar blocks of concrete may sometimes be used in the influent channel to divide the flow. Leveling the outlet weirs is necessary to equalize the distribution between units. In many long tanks, where most of the solid may tend to settle at the influent end, channels are provided to reverse the flow. This permits the maximum use of the entire digestion space. If uneven sludge distribution occurs, the flow must be reversed each month. The influent and effluent baffles in settling compartments should NOT extend more than 18 inches below the sewage surface. The influent baffle distributes the incoming flow more equally across the compartment section.

Removal of Scum

The sides and bottom of influent channels should be scraped daily, or more often if necessary, to keep these channels free of grease, scum, and gritty deposits. Deposits of grease and scum that adhere to tank walls at the waterline are removed daily by hosing and scraping to prevent an odor nuisance. Material floating on the surface is skimmed off several times daily. A conventional skimmer can be made with a pole long enough to reach all parts of the tank. A 1/4-inch mesh galvanized screen, attached to a heavy wire ring and formed into a 10-inch square basket with a tapered bottom, is attached to the end of the pole. A perforated scoop on a pole is also handy for skimming influent channels. The construction of these tools is illustrated in figure 12-10.

When material is being skimmed off, the sewage must not be disturbed so much that skimmings pass under the baffles. A continuous spray of water helps to settle floating solids. Placing skimmings in the gas vents is not recommended because it is easily overdone and causes odor problems. Petroleum oil must never be placed in gas vents. Skimmings may be buried or may be burned in an incinerator. If buried, they must be promptly covered with earth; 6 or more inches of earth must be added after the first 24 hours. At naval activities where there is a sanitary fill, the skimmings are collected in a covered container and transported daily to the fill.

Cleaning Sloping Bottom and Slot

Solids that adhere to the sloping bottom of the upper compartment must be pushed into the slots with a squeegee once a week or more often if necessary. This squeegee can be fabricated from a long pole and rubber belting mounted on a crosspiece of suitable width. In addition, the slots must be cleaned by being dragged with a 3-foot, heavy chain mounted on a pole. Excessive stirring, which interrupts normal settling, must be avoided in these operations.

In regards to other cleaning requirements, note that all walks, wall tops, and exposed

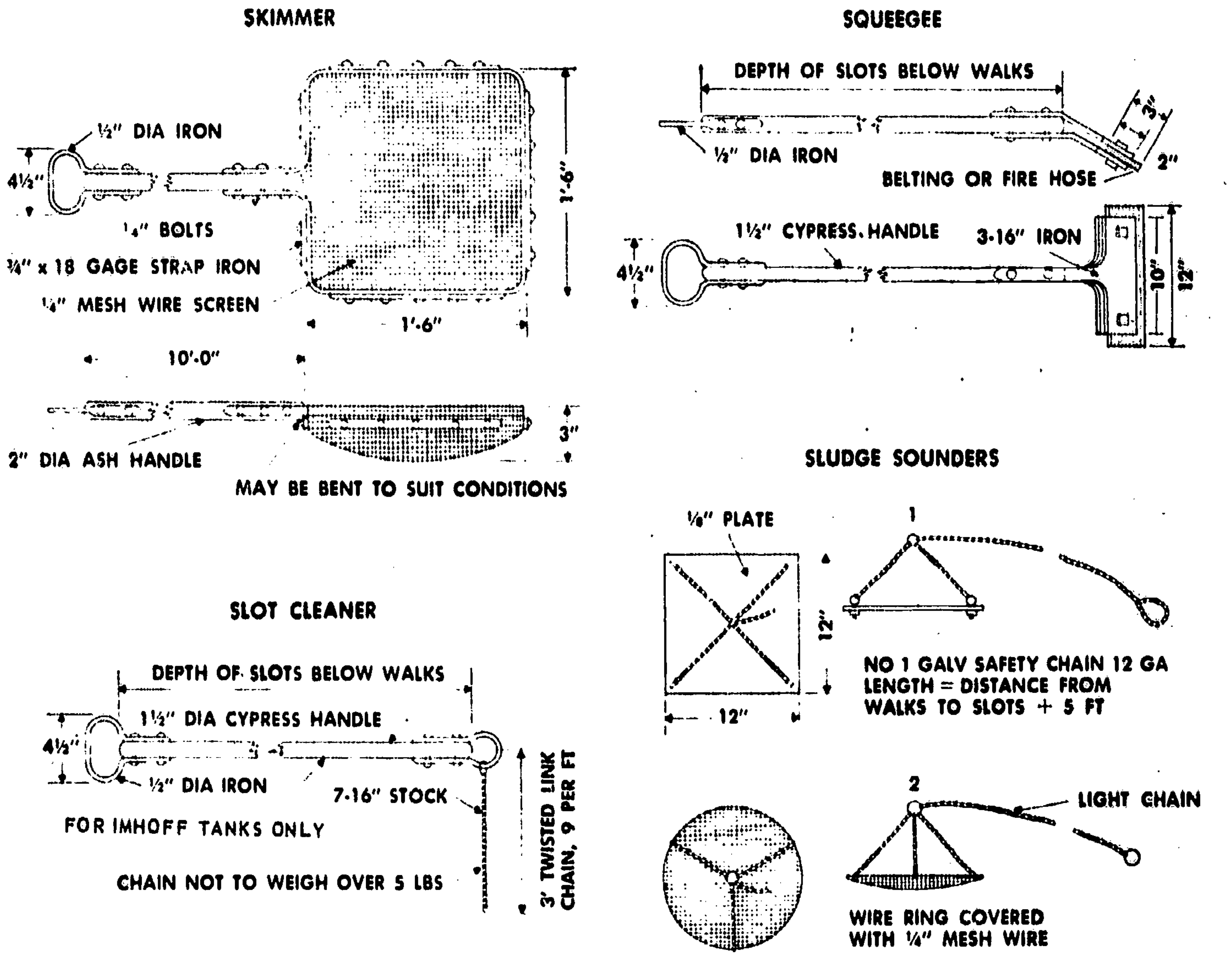

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Figure 12-10.—Homemade tools for sewage treatment facilities.

interior walls should be washed down at least once a day.

OPERATION OF DIGESTION COMPARTMENT

The single compartments are normally kept full of sludge, but not above a level of 18 inches below the slots. When the settling compartment slot is not properly trapped, it may be necessary to hold the sludge level much lower to prevent sludge solids from passing upward through the slots. Withdrawing small amounts of sludge monthly is a better practice than drawing off large quantities at longer intervals. Only well-digested sludge is drawn, with enough digested sludge remaining to provide proper seeding and to prevent acid digestion and foaming. Usually not more than half the depth of sludge in the tank may be removed at any one time. This procedure must be changed during the winter in northern climates, because of slower digestion rates and the lack of sludge-drying facilities. The sludge level must be lowered during the summer and autumn to allow space for the winter accumulation. At some facilities, withdrawal must be regulated according to the availability of drying beds. Sludge must be drawn down before long rainy seasons to allow for adequate capacity.

Removal of Digested Sludge

Digested sludge, when removed, is black and granular and has an inoffensive tar-like odor. It also has a pH normally above 7.0. It drains and dries readily on sand beds. Digested sludge must be drawn slowly to prevent a cone from forming within the sludge and to prevent partially digested sludge and sewage from being removed. After sludge has been drawn, the lines are flushed out and filled with water (unless there is danger of freezing) to prevent drying and hardening of solids within the pipes. If sludge clogs the withdrawal pipe, the flow may be started by agitating the sludge with long rods through the slots, gas vents, or the sludge riser pipe. Recirculated effluent or water under pressure (not connected to a potable system) may be used through a hose immersed in the sludge riser pipe. Opening and closing the sludge valve may also relieve clogging.

Measurement of Sludge Depth

When the treatment facility is operating near capacity, the sludge depth in the sludge compartment is determined at the inlet and outlet ends of the tank once each week. If less than 75 percent of the sludge compartment capacity is in use, monthly measurements are adequate.

Several methods may be used in measuring the sludge depth. One method is to equip a pitcher pump with a rubber suction hose, weighted on the end, with markings on the hose at 2-foot intervals. Lower the hose gradually through the slot in the settling compartment while the pump is in operation. The length of hose that is immersed when sludge first appears is equal to the depth of the sludge.

Gas Vents

The surface of gas vents must be broken up and wetted once each week, or more often if necessary, to allow gas to escape and to facilitate scum digestion. One or more of the following methods may be used:

1. Work scum with rake, hoe, or other suitable tool.
2. Hose scum with a fine spray of water under pressure. Do not use large volumes of water, which will start currents upward through the slots.
3. Keep the scum wetted down with sewage or preferably liquor from the digestion compartment by using a portable pump. Avoid using large quantities of water.
4. When heavy, dry scum is two or three feet deep, remove it with shovels or forks and place it on drying beds.

Foaming

Foaming is characterized by an excessive, frothy, odorous scum that fills the upper part of the digestion compartment and gas vents and often rises through the slots. It is caused by raw solids that accumulate faster than they can be digested. Foaming results in a predominance of the acid stage of digestion, a lowering of the pH, and a rapid formation of gas. The gas produced during foaming is high in carbon dioxide content and may not burn in boilers and heaters. The following conditions may induce foaming:

1. Starting a tank without seeding the sludge.
2. Low winter temperatures, which hinder digestion, followed by the higher spring and summer temperatures.
3. Excessive withdrawal of sludge.
4. Insufficient digester capacity.

In most cases, foaming can be prevented by careful operation. When foaming occurs, it may be controlled by one of the following methods:

1. In starting a tank, use digested sludge, if available, to hasten normal digestion.
2. Place the tank out of service until the action subsides if more than one tank is provided. However, the increased load on the other tanks may cause them to foam. In addition, the sewage in the settling chamber of the resting tank will become septic and odorous. As an alternative to this method, reduce the flow to the Imhoff tank, avoiding a detention period of more than 6 hours. Avoid septic conditions in the settling compartment when the Imhoff tank is followed by aerobic secondary treatment.
3. Break the foam by periodic heavy hosing or preferably by a continuous fine spray of water. Do not add large quantities of water, which would force an equal volume of septic liquor or foam up through the slots and harm the tank effluent.
4. Apply sludge compartment liquor or sludge from the hopper-bottoms to the gas vents with an airlift or portable pump. This method tends to mix the foam with digested sludge.

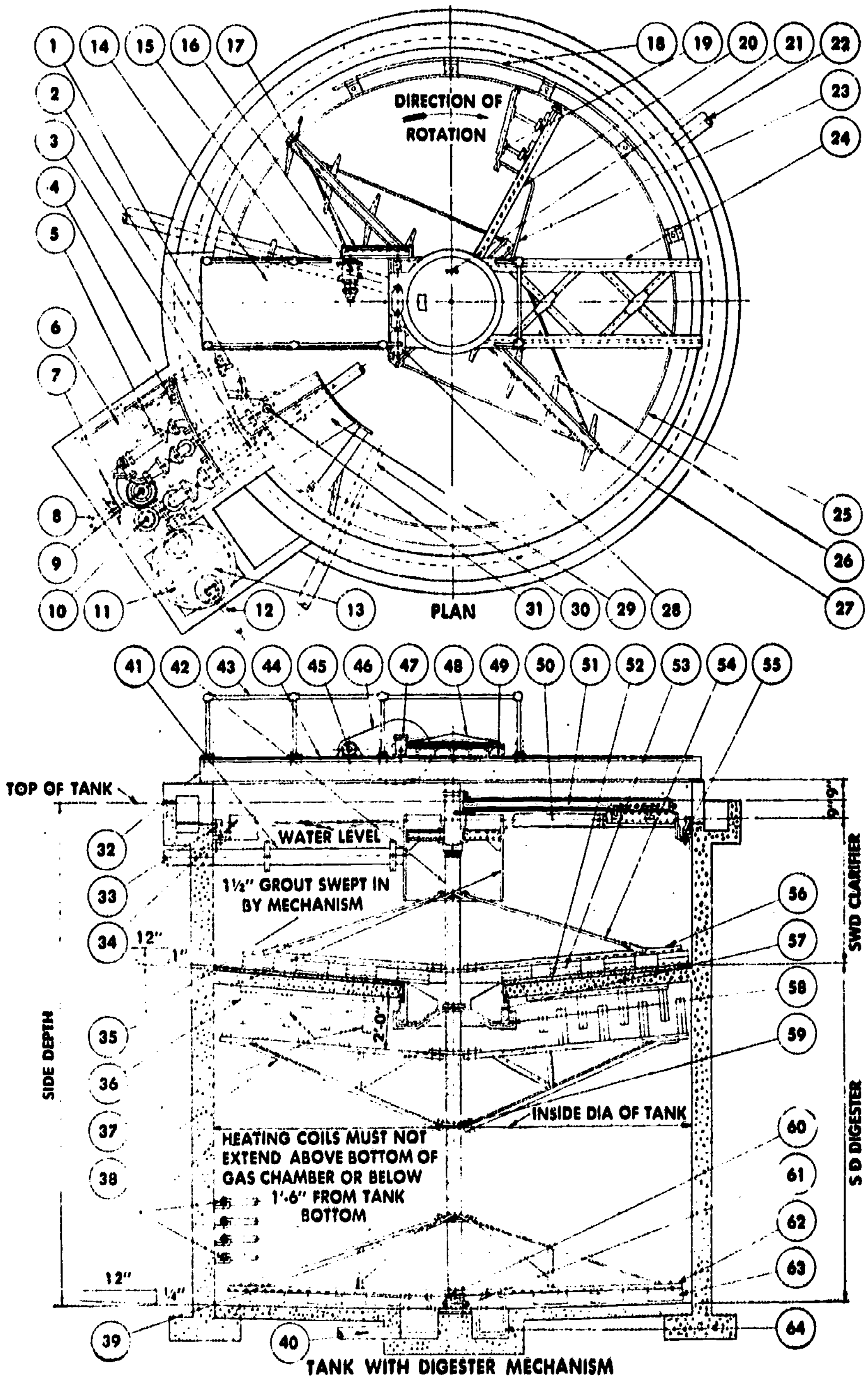

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Figure 12-11.—Clarigester.

Nomenclature for figure 12-11.

1. 2" Scum return to influent well.	33. Weir.
2. 6" Sluice gate.	34. Scum baffle.
3. 6" Supernatant return to influent well.	35. Influent well.
4. Access opening.	36. Stationary scum breaker.
5. 2" Scum return to influent well.	37. Pickets.
6. Scum pit.	38. Scum-breaker arm.
7. 6" Sluice gate.	39. Tie-rod spider.
8. 6" Drain pipe.	40. Sludge pipe.
9. Scum pump.	41. Influent pipe.
10. 6" Adjustable supernatant overflow.	42. Center shaft.
11. Ladder rungs.	43. Handrail.
12. 2" Gas line.	44. Walkway.
13. Gas dome.	45. Drive unit.
14. Walkway.	46. Chain guard.
15. Influent.	47. Overload alarm.
16. Drive unit.	48. Worm-gear cover.
17. Chain guard.	49. Drive head.
18. Effluent weir.	50. Skimming blade.
19. Skimming blade.	51. Skimming arm.
20. Skimming arm.	52. Squeegees.
21. Drive head.	53. Blades.
22. Effluent pipe.	54. Tie rod.
23. Skimming blade.	55. Weir.
24. Mechanism support.	56. Rake arm.
25. Scum baffle.	57. Tray sleeve.
26. Blades.	58. Boot.
27. Rake arm.	59. Spider.
28. Overload alarm.	60. Spider.
29. Scum trough and shelf.	61. Lower guide bearing.
30. Sluice pipe to pump.	62. Rake arm.
31. Scum drain to pit.	63. Blades.
32. Mechanism support.	64. Center scraper.

5. Paddle the foam in the vents with a hose.

6. Use a hydrated lime suspension if the sludge pH is below 6.5. Do not use either pebble lime (also called unslaked lime or quicklime) or construction lime. Keep the digestion compartment free of deposits of undissolved lime, which hardens and is difficult to remove. Put lime in thin suspension into the sludge compartment through a pipe inserted into the gas vents at different points. Add only enough lime to raise the pH to 7.0. The amount needed is determined by the trial addition of lime suspension to measured quantities of sludge or gas-vent liquor from the tank.

7. Remove sludge during the foaming period if the sludge compartments are heavily loaded. Apply hydrated lime during the drawing to reduce offensive odor and fly breeding.

CLARIGESTERS

The clarigester (another of the dual-compartment tanks) is a single-two-story structure, similar in principle to the Imhoff tank, in which two separate operations take place; the settling of solids in the upper compartment and the digestion of the solids in the lower compartment. Its mechanism allows better control, provides for heating the sludge, and is generally more flexible in operation than the Imhoff tank. One type of clarigester is illustrated in figure 12-11.

Sewage enters the central feed well of the upper compartment and settled sewage flows over the weir near the rim of the tank. Solids settle in the upper compartment and are mechanically raked to the center for discharge through a sludge seal into the lower compartment where they are stored to permit digestion. The motor-driven mechanism has two radial arms with raking blades, which sweep the upper surface of a dish-shaped floor that divides the tank into the two compartments. A revolving skimmer arm carries a baffle and a pivoted skimming blade, which move floating solids toward a trough at the tank wall. The collected scum is carried through the trough to the scum pit.

The digester mechanism has two revolving radial sludge-stirring arms near the tank bottom, two scum-breaking arms located just below the ceiling, and a covered gas dome for gas collection and takeoff.

The scum pit, or transfer box, on the side of the tank is equipped with a pump. This pit may receive digester supernatant or settling compartment scum.

Piping is provided to permit pump discharge to enter either the settling or the digester compartments. Coils may be provided for heating the digester.

OPERATION OF SETTLING COMPARTMENT

Except for sludge removal, the clarigester operates similarly to the circular settling tank, which has a mechanical sludge collector. (See figs. 12-12 and 12-13.) Raw sludge drops through the trapped hole in the settling compartment floor into the digester at the same time that the supernatant is removed from the digester. If sludge appears on the settling compartment surface, it is not transferring properly to the digester and one or more of the following corrective procedures can be followed:

1. Withdraw more supernatant.

2. Check to see that the sludge seal is not clogged with screenings, sand, or some foreign object by shutting off the mechanism and prodding around the settling compartment with a long pole. In extreme cases, lower the water level for a direct inspection. Screenings that pass through the bar screen are likely to cause blockage. Remove them regularly and carefully.

3. Pump less scum liquid into the digester compartment. A high pumping rate, without a

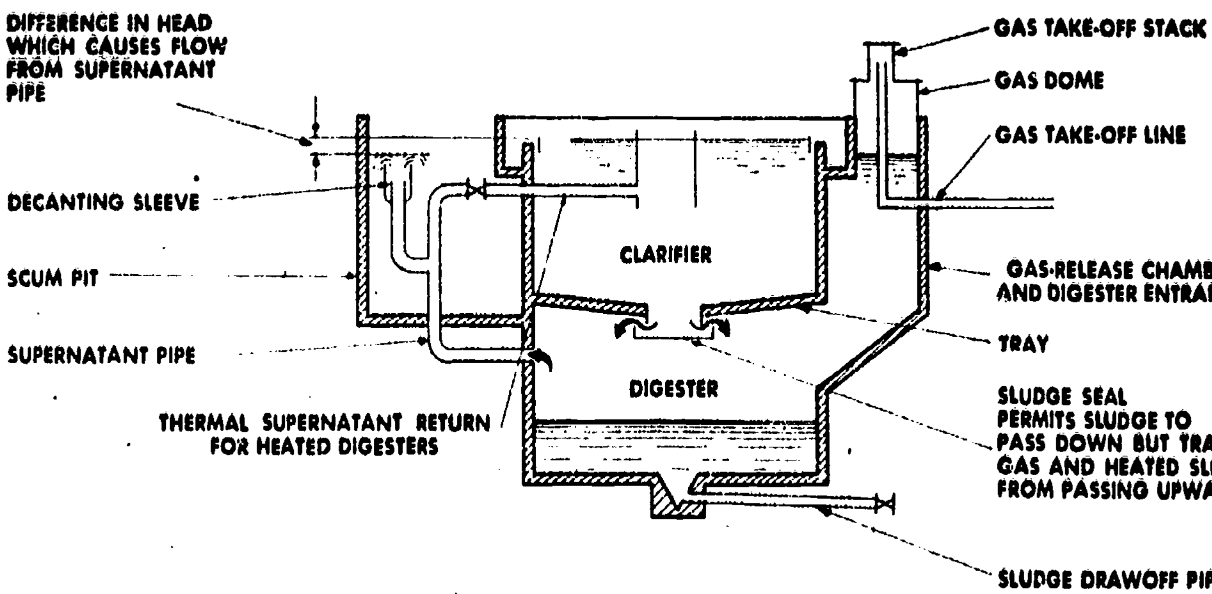

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Figure 12-12. — Operation of clarigester.

compensating supernatant withdrawal, forces digester contents back through the seal.

HANDLING SCUM

Scum from the settling compartment should be pumped to the digester. To keep down the quantity of water added to the digester, determine the thickness of the scum layer on top of the clearer liquor in the scum box before starting the pump. Pump the clearer liquor into the settling compartment, switching the valves just as the scum load is reached to send it to the digester. Whenever the scum pit is drained, hose it down thoroughly to avoid odors. If the quantity of scum is too much for the digestion compartment, dispose of it by incineration or burial.

OPERATION OF DIGESTER COMPARTMENT

The operation of the digester compartment of the clarigester is similar to that of the separate sludge digester.

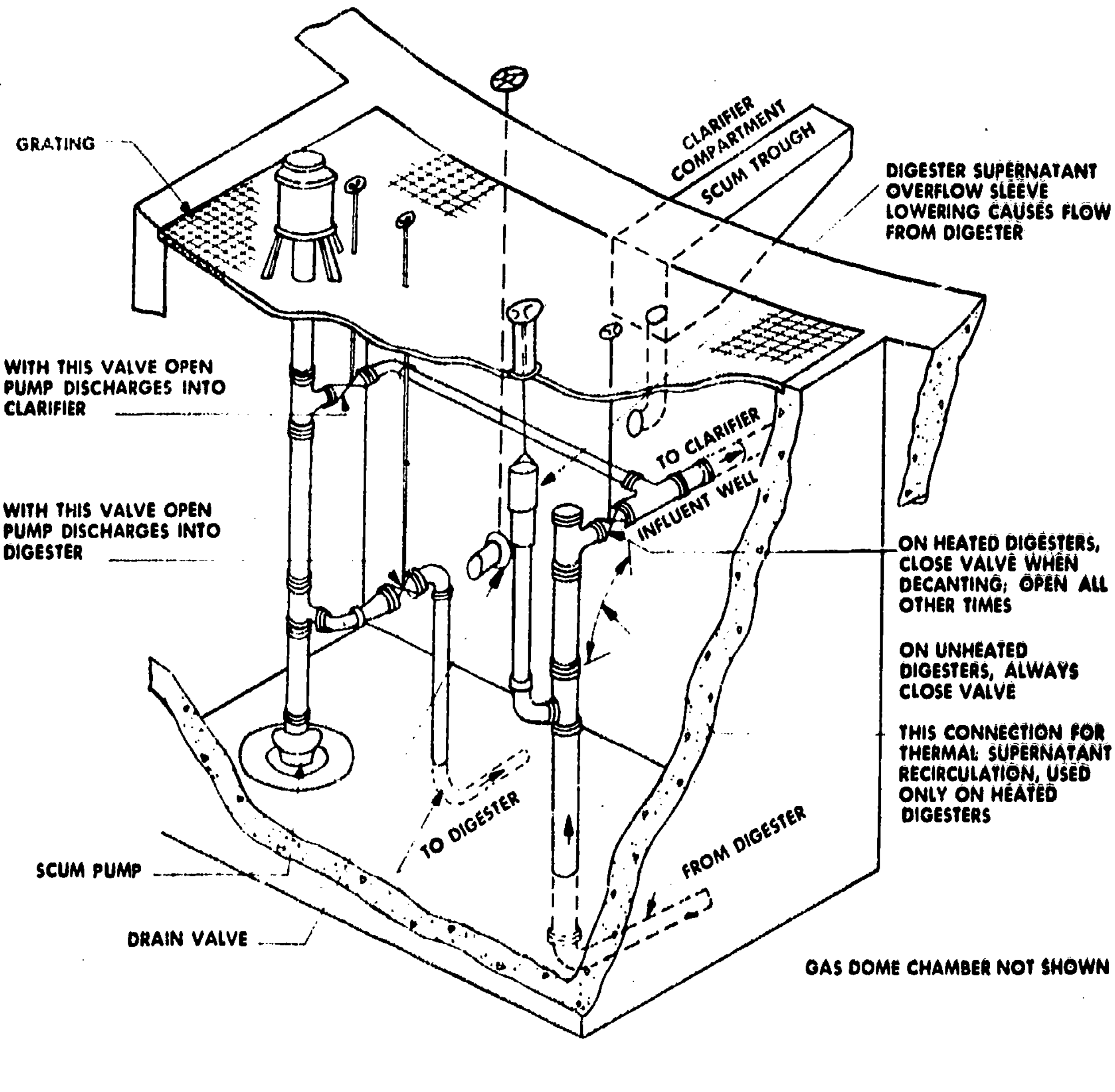

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Figure 12-13.—Arrangement of scum-pit piping.

The starting operation is as follows:

1. Heating. Fill the clarigester with sewage or water and heat the contents of the digester compartment with an auxiliary boiler to about 80° F before allowing sludge to accumulate.

2. Alkalinity control. Seed the digester if feasible. In the absence of seeding and during the initial operation, add enough hydrated lime to maintain a sludge pH of 7.0 to 7.4.

3. Make a lime slurry in a barrel for the liming process. Dump the slurry into the scum pit, and pump it into the digester.

4. Flush the pit and pump for a few minutes with sewage from the scum trough or settling tank drain.

5. Check the pH of the supernatant daily.

6. Several hours after adding the lime, take a sample to determine the pH. Find the proper amounts and frequency of lime additions through trial by using a 1-gallon sample of sludge and adding a known amount of the lime slurry.

Gas Production

Because gas production does not start for several days after the initial operating period, leave the gas dome cover off for observation. As the pH approaches 7.0 or above, gas production increases until odor and boiling action are noticed in the dome. After ensuring that the gasline is clear, install the gas dome cover. The gasline should have a moisture trap and flame arrester, and it is usually connected to a waster gas burner. After the dome cover is fastened and the air is flushed from the lines, gas at the burner should support combustion unless it is still too low in methane content. In this case, check again after a day or so.

Supernatant Overflow

Lowering the sleeve or decanting valve causes fresh sludge to flow from the settling compartment to the digester compartment, and also causes supernatant to flow from the digester to the box. Operate the supernatant overflow to maintain a low sludge level in the settling compartment. During the initial operating period, until correct practice is established, lower the sleeve 2 to 4 times a day, for about 15 to 30 minutes, with about 1/2-inch flow depth over the lip. When the clarigester is operating near capacity, operate the supernatant overflow every 4 hours. Pump supernatant to the settling compartment. If the temperature difference between the digester and the settling compartment is 20° F or more, the supernatant may be returned to the settling compartment without pumping if the valve on the supernatant return line is open. Partially close the valve to cut down the automatic return to the desired quantity. Close the valve when the pump is used or when the adjustable sleeve on the overflow is lowered. For an unheated digester, keep the valve closed; for a heated digester, lower the adjustable sleeve for a few minutes daily and check the quality of supernatant observed. If the supernatant contains much solid matter, sludge in the digester may have reached the drawoff level, which is about 4 feet below the top of the settling compartment floor at the side of the tank. Withdraw sludge when this level has been reached.

Scum

Occasionally, open the handhole of the gas dome to check for scum, which should be removed. If the material on top is sewage sludge instead of scum, sink it by stirring. Ladle out such accumulated indigestible material as hair, sticks, matches, and bottle caps. The sluice gate in the dome of the water level is used to withdraw scum into the scum pit.

Sludge Withdrawal

After the digester is operated for several months, it fills with digested sludge until an overload may be caused. Before an overload occurs, draw out some of the digested sludge. Before drawing sludge, see that it is properly digested. Properly digested sludge is granular, without an unpleasant or sour odor, and normally has a volatile-solids content below 55 percent. Draw sludge when the supernatant becomes thick with solids; this normally indicates that the sludge is within 2 or 3 feet of the tray. Draw sludge slowly onto the bed, opening the drawoff valve only slightly to prevent semidigested sludge or liquor from funneling through. Slow withdrawal discharges any sand in the tank and prevents a drop in the water level below the weir in the settling tank. Where sewage is pumped to the clarigester, keep the pump operating while drawing. Always leave at least 3 feet of sludge in the digester to seed the new sludge. Compute the digester content between the supernatant takeoff and the 3-foot level so that the amount going into sludge beds of known size can readily be determined in advance. If the scum pit has a sampling valve with piping extending down into the digester compartment, stop drawing off sludge when the flow from this valve starts to run thin. Withdrawing too much sludge may upset the operation to the extent that the digester operation may perform like a newly started unit.

Gas Hazards

Digester gas burns and, when mixed with the right amount of air, is explosive; it may also be toxic (or poisonous). To ensure safety at all times, observe the following rules:

1. Post a danger sign near the gas dome.

2. Keep all lighted cigars, pipes, cigarettes, or open fire away from the digester at all times.

3. Do not inhale digester gas.

4. Do not enter the digester unless it is empty of all sludge and forced ventilation has cleared it of gas. Use a lifeline with two men above. Remember that no ordinary gas mask supplies oxygen.

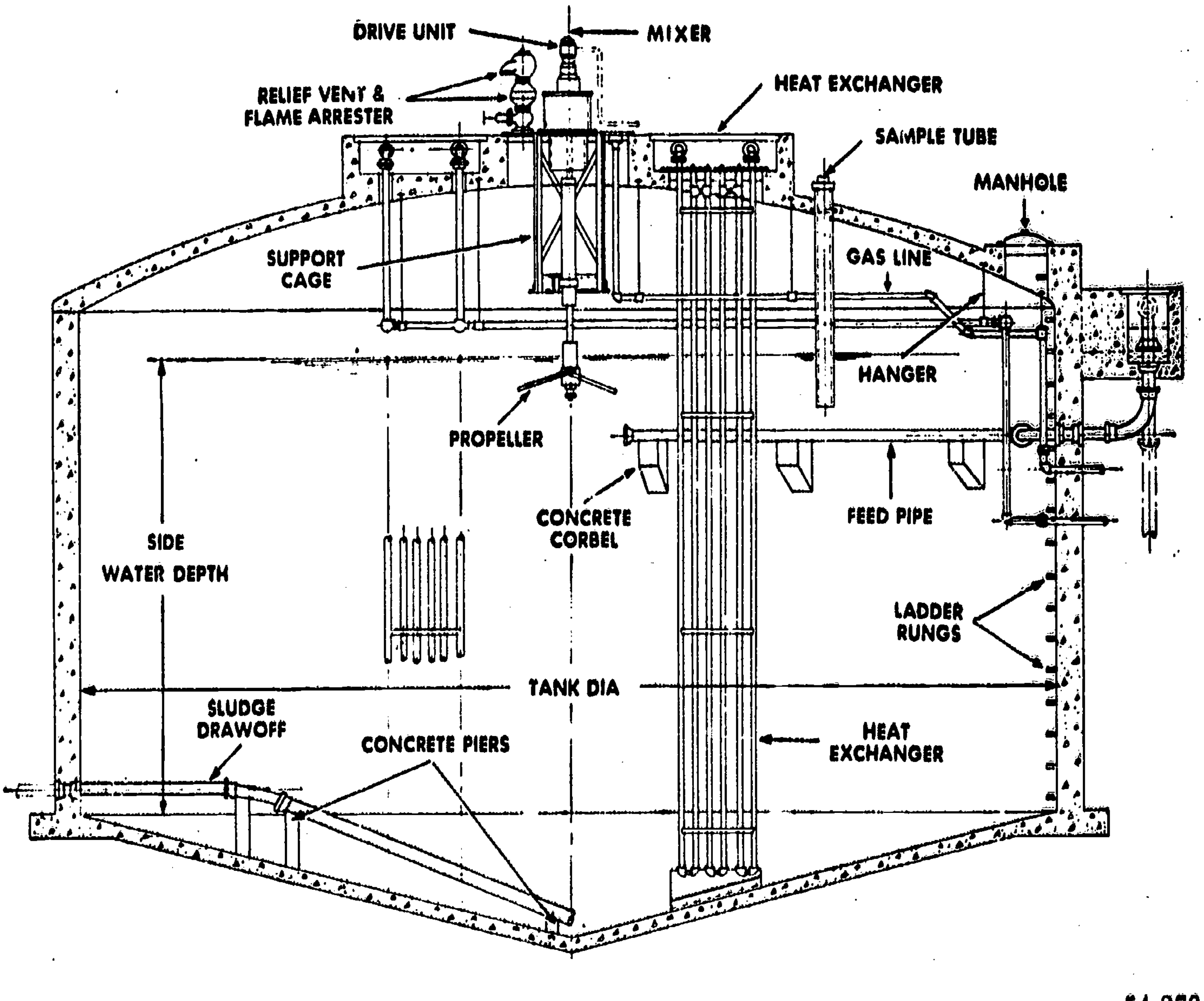

Figure 12-14.—Digester with fixed cover.

SLUDGE DIGESTERS

The sludge that is collected in settling tanks is usually treated in a separate sludge digester unless it is returned to the sewage flow. This unit changes the sludge into readily disposable products with minimum interference with other plant operations. Organic matter in the sludge furnishes food for bacteria, which break it down into simple, more stable substances by anaerobic decomposition. The final products of the digestion are more or less stable, humus-like solid matter (digested sludge); sludge liquor, including liquefied and finely divided solid matter (supernatant liquor); and gases. The digested sludge must be put on drying beds, the supernatant liquor is usually returned to the plant influent, and the gas is burned as waste or fuel.

Good mixing of fresh sludge with seeding material (digesting sludge) is essential to optimum operation. Considerable mixing is done naturally by the rising gas; in some digesters, additional mixing is done by mechanical stirrers or through recirculation by pumps.

Mechanical stirrers break up scum and keep grit removed from the floor, as well as mix the seeding material with the incoming sludge. This equipment is usually driven by an electric motor through a reduction gear and should be equipped for automatic shutoff and alarm in case of overload. On the singlestage digester, stirring equipment is cut off at least 1 hour before the withdrawal of the supernatant or digested sludge.

TYPES OF DIGESTERS

Digestion tanks are classified according to their construction or their operation. All of them have a sludge inlet at the side or the top, digested-sludge withdrawal line, and supernatant withdrawal at one or more levels. Types of digestion tanks used at sewage treatment facilities include UNCOVERED TANKS, FIXED-COVER TANKS, FLOATING-COVER TANKS, and GAS-HOLDER COVER TANKS.

UNCOVERED TANKS are usually hopper-bottom tanks without gas-collection or heating equipment. They are used on small units or for storing partly or fully digested sludge from other digesters.

FIXED-COVER TANKS are usually concrete structures with sloping bottoms and a permanently fixed cover. (See fig. 12-14.) The cover may be a flat concrete slab with or without space for gas above the liquid level, or the tank may have a dome of concrete or of steel with space for gas. They may or may not have mixing, scum-breaking, or heating facilities. A gas dome and seal, normally in the center of the cover, are connected to a boiler and/or waste burner. Heating facilities are hot-water coils attached to the walls of the tank or suspended from the roof.

Tanks with FLOATING COVERS are similar to the fixed-cover type except that the cover floats on the contents of the tank. (See fig. 12-15.) This cover has several radial trusses with a watertight, steel ceiling plate attached to the bottom chords. The outer ends of the trusses are joined by a vertical rim plate a few inches inside the tank wall. The rim plate extends far enough above the ceiling plate to provide enough buoyancy to float the cover. The floating cover keeps scum submerged. The gas dome is placed at the center of the cover.

Steel GAS-HOLDER COVERS are supported by gas pressure. A deep skirt, extending into the liquid, provides a gas seal around the edge, the cover rising and falling with varying gas volume in storage. The center column and guides at the outside edge prevent the cover from tipping. The liquid level and cover may be lowered about 5 feet during sludge withdrawal, but the tank is normally operated at the maximum liquid level.

Two or more digestion tanks provide flexibility of operation. They can be operated independently, as single-stage digesters in parallel, or as two-stage digesters in series, with one tank as a primary unit and the other as a secondary unit. Two-stage installations are frequently designed with a fixed-cover, heated, primary tank and a heated or unheated secondary tank with a gas holder. Gas from both tanks is collected in the secondary tank, whose cover provides storage and maintains gas pressure. Another type of installation permits either parallel or stage operation with each tank having heating facilities and floating cover. Digesters are usually made of concrete.

A two-story digester for two-stage operation also provides flexibility in the use of digestion tanks. (See fig. 12-16.) This unit has a primary-stage compartment in the upper portion and a secondary-stage compartment in the lower portion, with sludge passing to the lower compartment through transfer lines. The upper portion is heated; supernatant and gas may be withdrawn from either compartment.

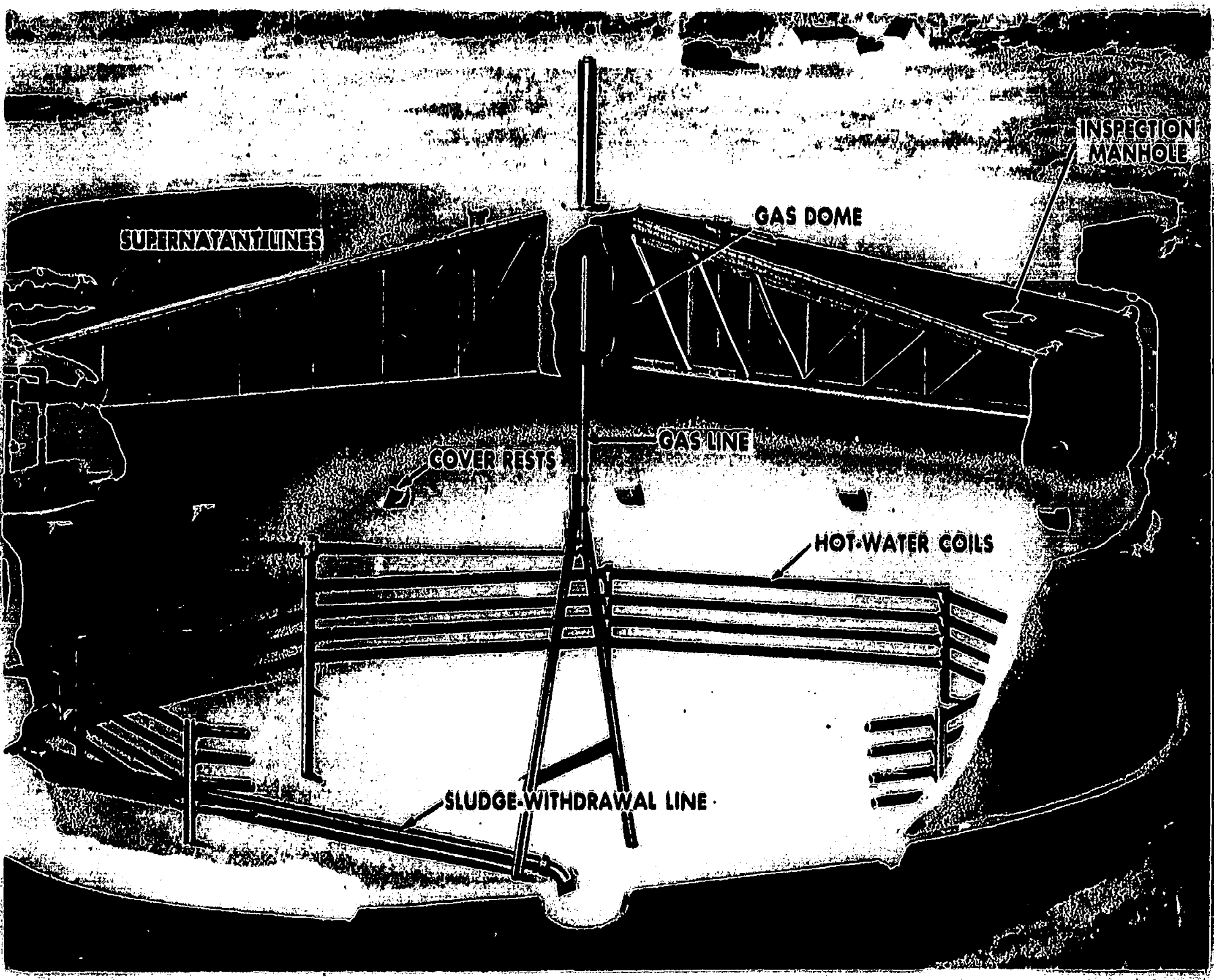

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Figure 12-15.—Digester with floating cover.

OPERATION OF DIGESTERS

Before tanks are put into service, they should be inspected carefully, all debris removed, valves and stirring mechanisms checked for proper operation, pressure-vacuum relief on covers adjusted, and all piping made tight and cleared of obstructions.

Fixed-cover digesters must be completely filled with raw sewage or water to eliminate the air accumulated below the cover. The handhole in the gas dome of floating covers should be opened and the tank filled enough to lift the cover from the landing brackets or low-level supports. Open tanks should be filled only as the sludge accumulates.

Seeding with either partially or well-digested sludge should be done wherever feasible. Sludge from septic tanks, Imhoff tanks, or other digesters may be transferred direct to the digester.

Heated Tanks

Tank contents of heated digesters should be brought to a temperature between 85° and 95° F. During the initial operation, not enough digester gas is produced to heat the contents. Where digesters are started in cold weather, auxiliary fuels, such as domestic or butane gas (bottled), should be used temporarily until enough digester gas is available. A temporary

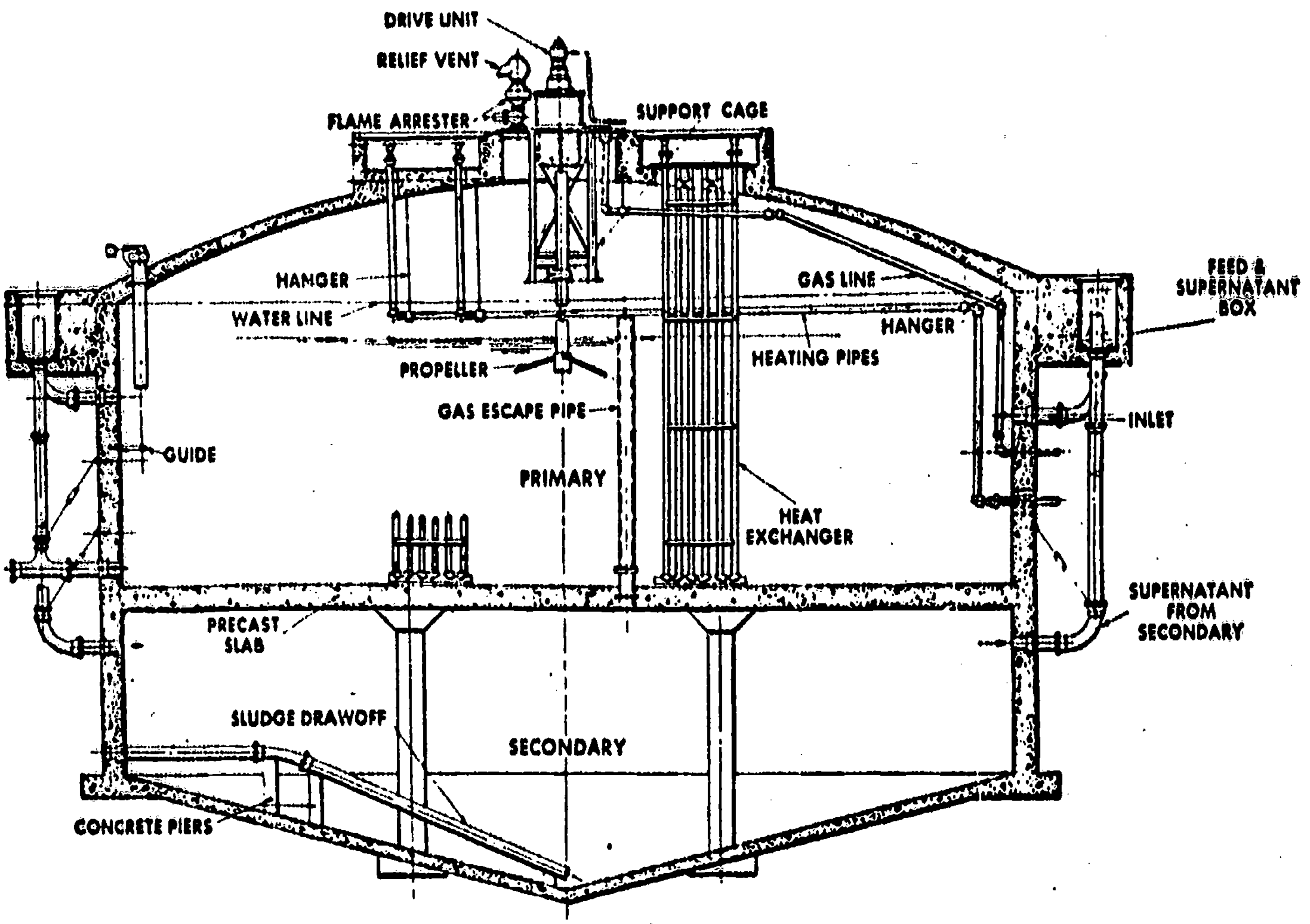

Figure 12-16. — Two-story digester.

gas connection and adjustment or replacement of gas-burner orifices may be necessary. Auxiliary boilers for burning oil or coal are often installed as regular equipment; a portable steam boiler may be used.

Unheated Tanks

Unheated tanks started in cold winter weather may be helped by the addition of lime. Daily pH determinations are made. When the pH falls to 6.5, lime is added to bring it up to 6.8. The quantity of lime needed is best determined by adding small known amounts of lime slurry to 1 gallon of sludge until the proper pH is reached. Lime made into a thin suspension is fed into the digester at a slow rate together with raw sludge.

Grease

Grease from skimming should not be transferred to the digester until digestion has reached normal operation.

Adding Sludge

Sludge should be drawn to the digester in fixed-cover tanks at frequent intervals and low rates to minimize disturbing the supernatant, which is discharged at the same rate and quantity as the sludge added. With floating-cover tanks, raw sludge additions may be less frequent, because the supernatant is not necessarily drawn off at the same time. Raw-sludge drawing is regulated largely by the requirements of the settling units. Where two or more digesters are operated in parallel, the flow may be divided between the tanks in proportion to their size or alternated between the tanks daily.

WITHDRAWAL OF SUPERNATANT

Excessive digesting solids in the supernatant that is returned to the raw sewage cause rising sludge in the primary settling tanks and impair the secondary treatment. Withdrawal is regulated to obtain supernatant with the lowest possible solids content (0.4 to 0.7 percent); it is done slowly, preferably during low flow periods. The solids content is observed at each drawoff level daily and the clearest level is selected for supernatant withdrawal.

The addition of raw sludge to a fixed-cover digester causes a simultaneous overflow of supernatant at the same rate after the initial liquid level rise. Limited control of the withdrawal rate is obtained by pumping sludge for short periods at frequent intervals to cause an almost continuous, slow discharge of supernatant. CAUTION: Supernatant outlet must be kept free. If the outlet is clogged, sludge pumping can raise or crack the digester cover.

In the case of a floating-cover digester, the supernatant is withdrawn slowly, beginning between 1 and 2 hours after the addition of raw sludge. If 2 tanks are operated in parallel and sludge is pumped to each tank on alternate days, the supernatant is withdrawn during the next day.

A well screen, or supernatant selector, mounted vertically in the digester, removes supernatant from the clearest layer, because heavy sludge or scum blocks the screen. Periodic backwashing with water under pressure is required; the frequency depends on the clarity of supernatant and the degree of sludge digestion. Because excessive grease in the digester plugs the screen rapidly, scum is disposed of by incineration or burial instead of by pumping to the digester.

The suspended-solids content of supernatant is reduced by aeration, with or without adding lime, to remove dissolved gases. After settling in a small tank in batches, the solids are returned to the digester and the clear liquid is returned to the raw sewage.

Supernatant is returned to the raw sewage at a point where it may be equally divided between primary tanks. A submerged outlet to raw sewage eliminates odors. The strength of the supernatant that can be returned to the raw sewage without decreasing the efficiency of the treatment is determined by local experience. Supernatant with a higher solids strength is treated before return, if facilities are available, and then is discharged to either a sludge bed, if capacity is available, or a lagoon.

When the supernatant is discharged to the surface of underdrained-sand sludge-drying beds, as little area as possible should be used. After such use is discontinued, dried scum on the bed should be removed and the sand surface broken, usually not more than 1 inch deep, by a rake or a hand harrow. Lagooned supernatant may be allowed to fill the lagoon, which must then be taken out of service and rested until digestion has been completed and a top liquor of low solids content has been obtained. The lagoon site should be selected carefully because odors develop.

WITHDRAWAL OF DIGESTED SLUDGE

The type of tank, disposal facilities, and the season of the year govern digested-sludge withdrawal. Enough digested sludge is left in the tank to seed the incoming raw sewage and to maintain balanced, alkaline fermentation. The amount of digested sludge kept in heated, controlled-temperature tanks depends on the efficiency of the sludge-drying or disposal facilities. These tanks may be used to store digested sludge when the season of the year makes proper sludge disposal impossible. The digested sludge in the tank must be reduced to a minimum before the cold or wet season. The season affects both digestion and sludge disposal of unheated tanks, located where their temperature falls below 75° F. During the warm season, they operate similar to the heated digesters; during cold weather, at least twice as much digested sludge must be kept in the tank to maintain alkaline digestion. A quantity of digested sludge must be left in these tanks before cold weather comes. For tanks operated in the recommended temperature range, the digested sludge should be at least 20 times the weight of volatile solids in the daily charge of raw sludge.

At normal operation, at least 4 feet of digested sludge above the hopper is needed to provide the proper proportions. The digested-sludge level is not too high until it interferes with the supernatant's quality. Where disposal facilities permit, sludge is withdrawn in smaller quantities, filling not more than one sludge bed at a time, once each month in smaller plants and as often as necessary in larger ones. The operator must stop drawing if any change in appearance indicates improperly digested sludge.

Sludge drawing is done slowly to minimize the disturbance of the digester. With floating-cover digesters, withdrawal should not be made when the cover is in the low position in the tank. With fixed-cover digesters, raw sludge should be pumped into the tank at the same time and at a rate at least as great as the digested sludge is withdrawn to reduce the danger of pulling air into the tank and to maintain gas pressure.

TEMPERATURE CONTROL

Heating equipment must be put into operation as soon as possible and constant temperatures between 85° and 95° F maintained. Water temperature in the heating coils to the digester should not be above 140° F; otherwise, sludge cakes on the coils, forming an insulating layer that reduces efficiency. The digester temperature is determined at least once each week. An approximate temperature may be obtained by checking the supernatant, but thermometer wells installed in the digester are more accurate. Digester temperatures at each 3-foot elevation are determined once each month with the aid of a wide-mouth-bottle sampler. Digesters are usually insulated by embankments or double walls. If digester temperatures cannot be properly maintained, construction of embankments should be considered.

SLUDGE CIRCULATION

The circulating of the sludge mixes raw sludge and seeding material in the tank. Where the recirculation enters at the top of the tank, the scum formation is broken. Recirculation also helps maintain alkaline fermentation. Where the need is indicated, digested sludge may be pumped back to the top of the digester for at least 1 hour each day after the supernatant has been withdrawn.

SCUM CONTROL

Digesters that operate within the recommended temperature range normally have a top layer of scum, usually a mat containing matchsticks, hair, and other light material that is hard to digest, bound together with grease and other sludge solids. Gas bubbles carry up entrained solids that deposit in the scum. These solids settle again, partially or totally. Normally, the scum need not be disturbed. Grease is readily digestible if it is kept wet and warm. If excessive greasy scum forms, pumping skimmings to the digester is discontinued. The bottom of the scum should be kept 1 or 2 feet above the supernatant overflow pipe; otherwise, scum may discharge with, or clog, the overflow.

Because the temperature in the upper part of the digester may be 20° to 30° F lower than the temperature in the rest of the tank, the scum formation may be lessened by insulating the digester cover to maintain a higher temperature at the top. Wetting and warming the scum layer, recirculating the sludge or supernatant to the top of the digester, or raising the digester temperature to 95° or 100 ° F helps to break up the scum. Where the layer is excessively thick, it can only be broken and removed by manual labor.

FOAMING

The causes of foaming and the methods of control in the separate sludge digesters are the same as those in the Imhoff tanks. The maintenance of the proper digester temperature prevents foaming unless tanks are grossly overloaded or seed sludge is depleted.

GAS-UTILIZATION EQUIPMENT

The rate of gas production and composition of gas indicate digester activity. Several factors govern the volume of gas obtained from digesters, particularly the degree of digestion and character and amount of volatile solids in the material. Gas volume produced is expressed in terms of the number of persons served, weight of volatile solids in the raw sludge, or the weight of volatile matter destroyed by digestion. The gas volume usually ranges from 0.7 to 1.2 cubic feet per capita per day, or from 6 to 12 cubic feet per pound of volatile matter in raw sludge. Sludge gas usually contains 60 to 73 percent methane, 20 to 35 percent carbon dioxide, 1 to 10 percent of nitrogen, and small quantities of hydrogen sulfide, hydrogen, and oxygen. Analysis for carbon dioxide only is enough for routine control. Close observation and recording of the gas production and a weekly gas analysis will effectively measure digester activity. A high rate of gas production with carbon dioxide content below 30 percent indicates good digestion; increasing carbon dioxide content shows a trend toward acid digestion.

Sewage gas is commonly used for heating water to maintain digester temperature. It also is used as a fuel for heating buildings, laboratory burners, screening and grease incineration, and gas engines driving pumps, blowers, or electric generators. Excess gas is burned in a waste-gas burner. Since fixed and floating covers with gas domes have a limited gas-storage capacity, gas-holder covers and separate gas-storage tanks are sometimes provided.

MAINTENANCE OF DIGESTERS

The following procedures are recommended for maintenance of digester units:

1. Inspect the unit to prevent overloading. Check the operation of the overload pointer; it should move to the left to indicate an overload. Make sure that sludge lines are not clogged and that the flow from the clarifier is not carrying too much grit or sludge.

a. If the overload results from clogged sludge lines, connect high-pressure water to discharge line and force water through that line. This clears most stoppages in sludge lines.

b. If excess grit or sludge from the clarifier causes the overload, operate the sludge pump connected to the digester underflow until all accumulated grit or sludge is removed.

c. Overload may result also if foreign objects are dropped into the tank. If they are not eliminated by pumping for a short time, stop the mechanism, back up the vertical shaft one-eighth turn, and resume operation. If this fails, shut down the mechanism and remove any foreign objects, emptying the tank completely if necessary. CAUTION: If large foreign objects, such as rocks or tools, are dropped into the digester, stop operation immediately and do not resume operation until the objects have been removed.

2. Spray gas dome. Water sprays may be provided in the gas dome of gas-collected-type digesters for use when scum tends to fill the dome and plug the gasoline. When too much scum forms, remove screens and operate water sprays to keep the foam down and clear the gasline. Remove scum through the scum drain from the gas dome as required.

3. Check adjustments and alignments. Inspect and tighten all bolts. Maintain the original adjustments and alignments.

4. Check mechanical parts. Test the overload-alarm bell and the automatic-cutout switch for proper working condition. Raise the overload pointer to see whether the bell and switch operate. Inspect all gears and working parts for excessive wear. Keep machine and surroundings clean.

5. Check the gas-dome seal to see that it is filled with water, light oil, or kerosene. When water is used, add antifreeze if freezing temperatures are expected.

6. Lubricate reducers and drive mechanisms in accordance with the manufacturer's instructions.

7. Inspect the oil in the speed reducers and oil baths and change oil if necessary, using the proper grade for summer and winter.

8. Check mechanical parts on the clarigester.

a. See that the drive unit is lubricated.

b. Inspect and tighten all bolts. Maintain the original alignments of the machine.

c. Test the overload-alarm bell and cut-out switch by raising the overload pointer and noting whether the bell and switch operate.

d. Check the motor condition.

10. Check the unit if an overload occurs. If foreign objects, such as tools, samplers, and the like, are dropped into the tank, stop the mechanism immediately and remove them. If the overload device stops the mechanism, determine and eliminate the cause before starting the unit again. Do not tamper with overload switch adjustments to force the machine to operate against an overload. Remove the drive chain from the motor, back up the worm by hand for 10 to 15 turns, and start the mechanism. If an overload is still indicated, empty the tank and remove any obstruction. To overcome an overload caused by the accumulation of sand and grit in the digester, remove several feet of sludge from the digester.

SLUDGE DRYING AND DISPOSAL

Well-digested sludge from the separate sludge digester or the Imhoff tank has a water content of 90 to 96 percent. Digested sludge is generally dewatered at the treatment facility by underdrained sand beds, although natural sand areas are sometimes used. This sludge drying takes place by both evaporation from the surface and drainage through the sand and gravel. Water passing through the bed is returned to the raw-sewage flow where possible. When elevation of the treatment facility makes this return impracticable, the water is discharged to other points or to the receiving stream.

Quick and efficient drying of sludge depends on the proper functioning of the digester or

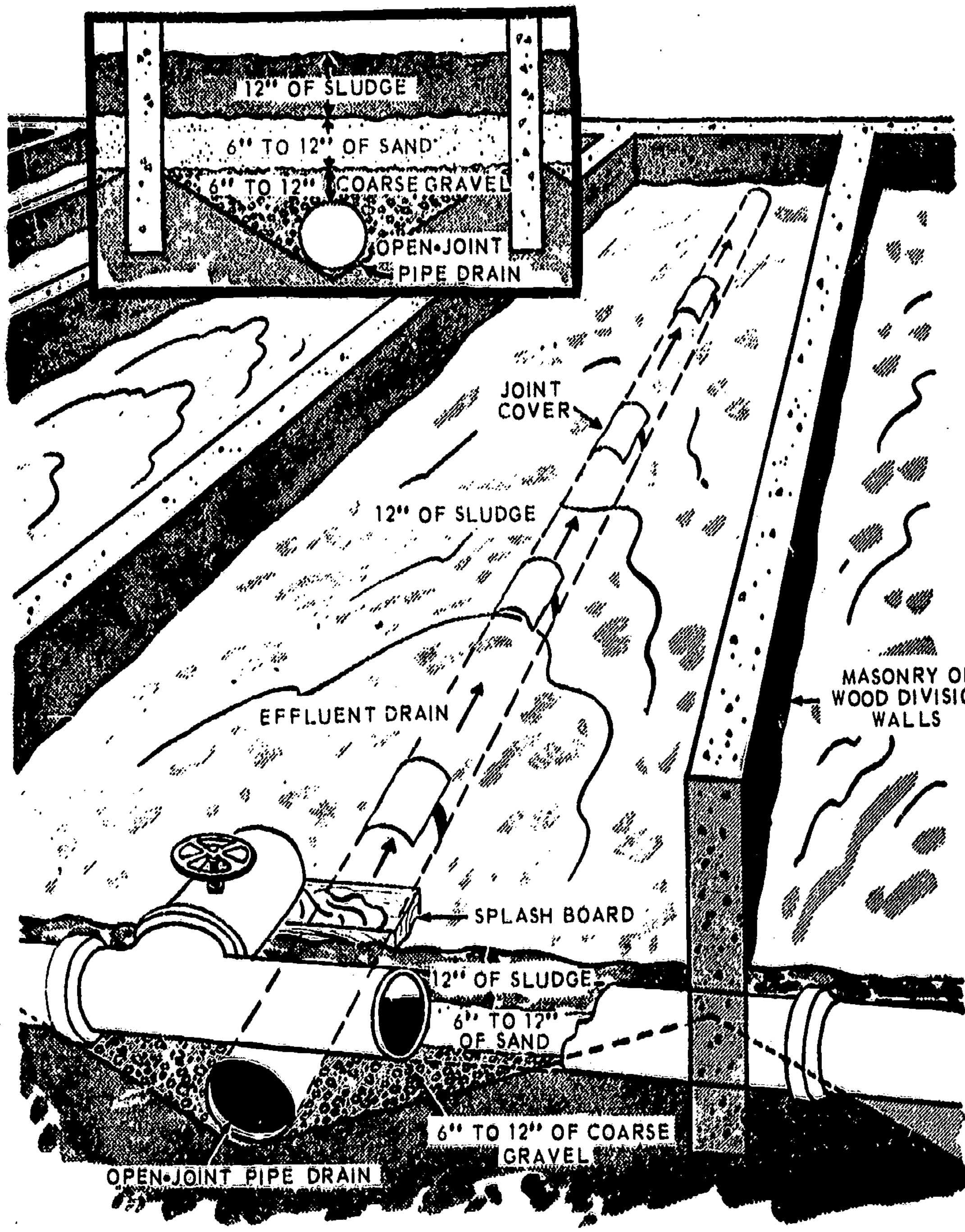

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Figure 12-17.—Sludge drying bed.

Imhoff tank to produce well-digested sludge. Total-solids content of well-digested sludge varies from about 4 to 10 percent; volatile-solids content (dry basis) is below 55 percent; and the pH is over 7.0. Poorly digested sludge forms a heavy, tenacious mat over both the sand and the sludge surface, which condition retards drying; undecomposed grease clogs the sand. Where digestion is inadequate, the condition of the sludge adversely affects the drying and produces objectionable odors.

Underdrained beds ordinarily are level areas of sand supported by graded gravel layers having open tile drains; the sand depth varies from 6 to 12 inches. (See fig. 12-17.) Floors are of natural earth with the dividing and outside walls of concrete, wood, or earth. The beds consist of a number of adjacent or independent units whose size depends upon the plant size and average drying time. A standard design for the construction of underdrained drying beds provides for 1 square foot of sand surface per capita and, for prepared natural areas, 2 to 3 square feet per capita. Glass-covered beds are used if the climatic conditions or a possible odor nuisance makes them necessary.

Weather conditions will affect the drying periods. In summer or in dry seasons, when digestion and drying proceed rapidly, the beds are recharged frequently. For unheated digesters or Imhoff tanks in cold climates, ripe sludge must be held in the tank during the cold weather unless glass-covered drying facilities are available. During cold or wet weather, drying on open beds is retarded and other means may be necessary.

Sludge beds must be clean before they are used. After dried sludge has been removed and before a new batch is added, the sand surface is loosened by light raking; it is then leveled with a slight slope away from the point where the wet sludge enters. Sludge chunks, weeds, and other debris are removed. When the sand layer decreases to 4 inches or less because of the removal of sand with the dried sludge, clean, coarse sand is added. Improper cleaning and poor preparation of the beds between sludge doses may clog sand surfaces and retard drying. Clogged sand surfaces may be remedied by removing the top 1/4 to 1 inch of sand. Sludge must be prevented from falling directly on the sand surface by the erection of an adequate splash plate of concrete, brick, masonry, or wood so that the surface is not appreciably disturbed.

Filling the bed to excessive depths may clog the bed and lengthen the drying time, because water must be lost then almost entirely by evaporation. The depth for optimum drying, which can be learned best by experience, is generally between 8 and 12 inches, depending on the solids content. The dried cake should be about 3 to 4 inches thick under normal drying conditions. If the sludge is comparatively thin, it dries quickly; but the thinner cake requires more labor to remove a unit volume than the thicker applications require. A greater percentage of sand is removed with thin cakes. If the bed area is limited, digested sludge must be drawn more frequently and applied at a minimum depth so that it can dry more quickly. Wet sludge cannot be discharged onto dried or partially dried sludge. Sludge lines are drained and flushed with a small amount of water or supernatant after each use to prevent the hardening of sludge in them. If partly digested sludge or supernatant is drawn to the bed, hydrated-lime or chlorinated-lime suspension may be used to arrest decomposition. Approximately 27 pounds of hydrated-lime suspension added to 100 pounds of dry solids in the raw sludge permits drying without offense. However, the sludge dries slowly and incompletely; removal is difficult; and the sand clogs. Raw sludge is added only in extreme emergency.

If the facility has insufficient sludge-bed capacity, the drying process is hastened by the use of coagulants. Alum solution is the most effective and economical agent for treating digested sludge before it is drawn to the sand beds. As little alum as possible, consistent with good results, should be used; 1 to 2 pounds per cubic yard (200 gallons) of sludge are usually required. The solution is prepared by dissolving the aluminum sulfate, which is placed in a gunny sack and suspended in a barrel of water, or by stirring or letting it stand overnight. The solution is mixed with the sludge by siphoning it into the sludge inlet to the drying bed.

Dried sludge is ready to handle when it can be picked up with a fork without excessive sand adhering to the underside. The moisture content of this sludge usually ranges from 55 to 70 percent. To avoid the removal of too much sand, forks rather than shovels should be used. Dried material may be moved from the bed by wheelbarrows, trucks, tractors, or carts. Trucks or other heavy equipment are not allowed on the beds unless runways are provided to avoid crushing and clogging the underdrains. The digested sludge may be used for fertilizer or fill on approved dumps or in low-lying areas.

If the sludge removed from drying beds is lumpy and difficult to spread, it can be broken up by running a tractor or other heavy equipment back and forth over the stock pile. Dried sludge may be pulverized by a mechanical grinder. This device requires that the sludge be well digested to proper dryness. If the sludge is too dry, it flies out of the machine; if it is too wet, it sticks and clogs the machine.

CESSPOOLS, SEPTIC TANKS, TILE FIELDS, AND LATRINES

Various facilities are used for the treatment and disposal of sewage at installations where common sewers are not available. These

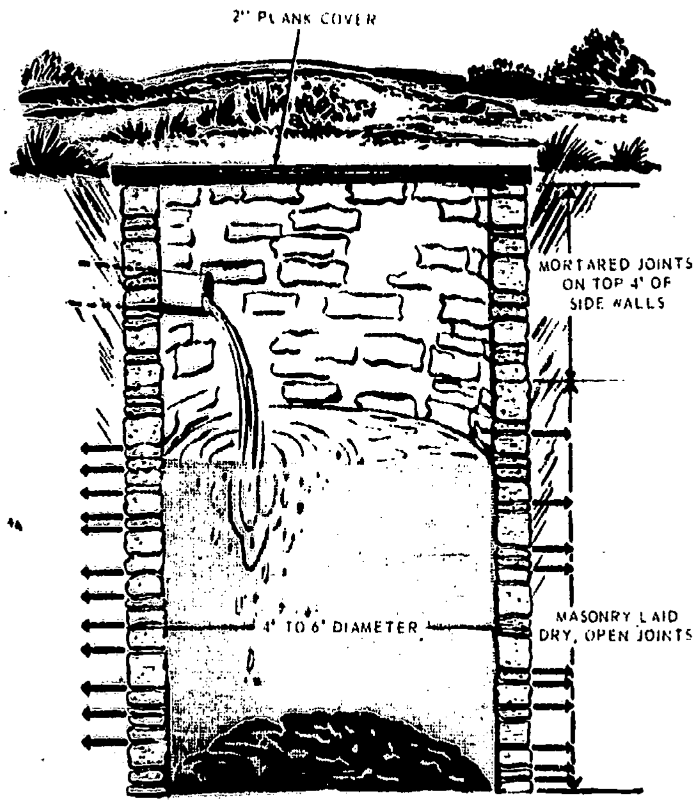

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Figure 12-18. — Leaching cesspool.

facilities include cesspools, septic tanks, tile fields, and field-type latrines. Information on each of these facilities is given below.

CESSPOOLS

Leaching cesspools are usually dry-laid masonry or brick-lined wells without any masonry at the bottom; the sewage flows into them and leaches out into the soil. Floating solids collect at the top and settling solids collect at the bottom of the well. The well's leaching capacity is exhausted when the solids accumulate and clog the soil. (See fig. 12-18.) The use of chemicals is not recommended to increase the useful life of a cesspool.

When the first cesspool becomes filled, a second well may be constructed to take the overflow from the first. In such cases, the first cesspool should operate as a septic tank to collect the settling and floating solids and provide a trapped outlet on the connection leading to the next leaching cesspool. Septic tanks may be placed advantageously ahead of leaching cesspools in larger installations. Leaching cesspools should not be placed closer together than 20 feet by out-to-out measurement of walls.

Leaching cesspools should be used only where the subsoil is porous to a depth of at least 8 or 10 feet and where the ground water is normally below this elevation. When they are located in fine sand, the leaching area can be increased by surrounding the walls with graded gravel.

The number and the size of cesspools that are required depend on the quantity of sewage and the leaching characteristics of the total exterior percolating area above the groundwater table, including bottoms and side walls below the maximum-flow lines. The allowable rate of sewage application per square foot per day, based on the recommended leaching test, is given below. Soils that require more than 30 minutes for a fall of 1 inch are unsatisfactory for leaching, and some other disposal method should be used.

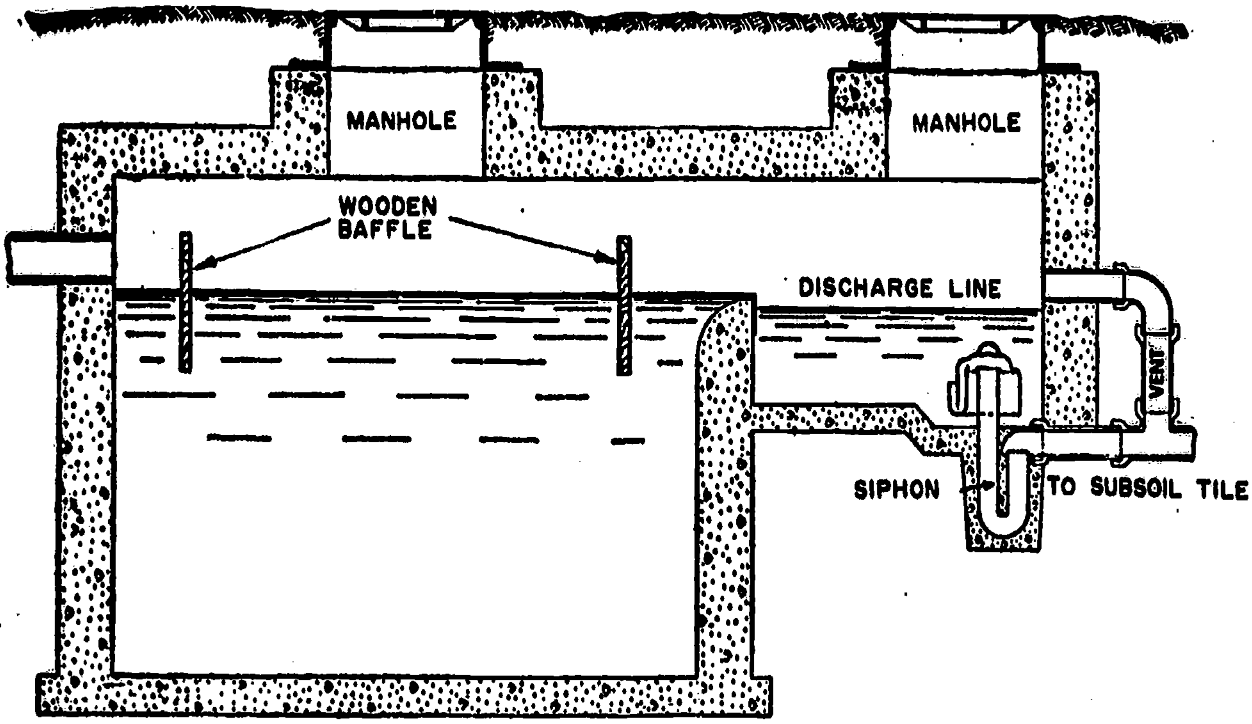
Time for water to fall 1 inch (minutes)	Allowable rate of sewage application (gallons per square foot of percolating area for day)
1	5.3
2	4.3
5	3.2
10	2.3
30	1.1

The test for leaching should be made by digging a pit about one-half the proposed depth of the cesspool, making a test hole 1 foot square and 18 inches deep at the bottom. The test hole is filled with 6 inches of water, which is allowed to drain off. Six inches of water is again added, and the downward rate of percolation is measured in minutes required for the water surface to lower 1 inch in the hole.

SEPTIC TANKS

For emergency and temporary construction, septic tanks are made of wood or nonreinforced concrete with wood covers and baffles. Reinforced concrete construction is more suitable for permanent installations. (See fig. 12-19.) The tank capacity should equal a full day's flow, plus an allowance of from 15 to 25 percent for sludge capacity. The minimum desirable size of tank is 500 gallons.

In constructing a septic tank, the length of the septic tank should be not less than 2 nor more than 3 times the width. The liquid depth should not be less than 4 feet for the smaller



54.109

Figure 12-19.—Septic tank.

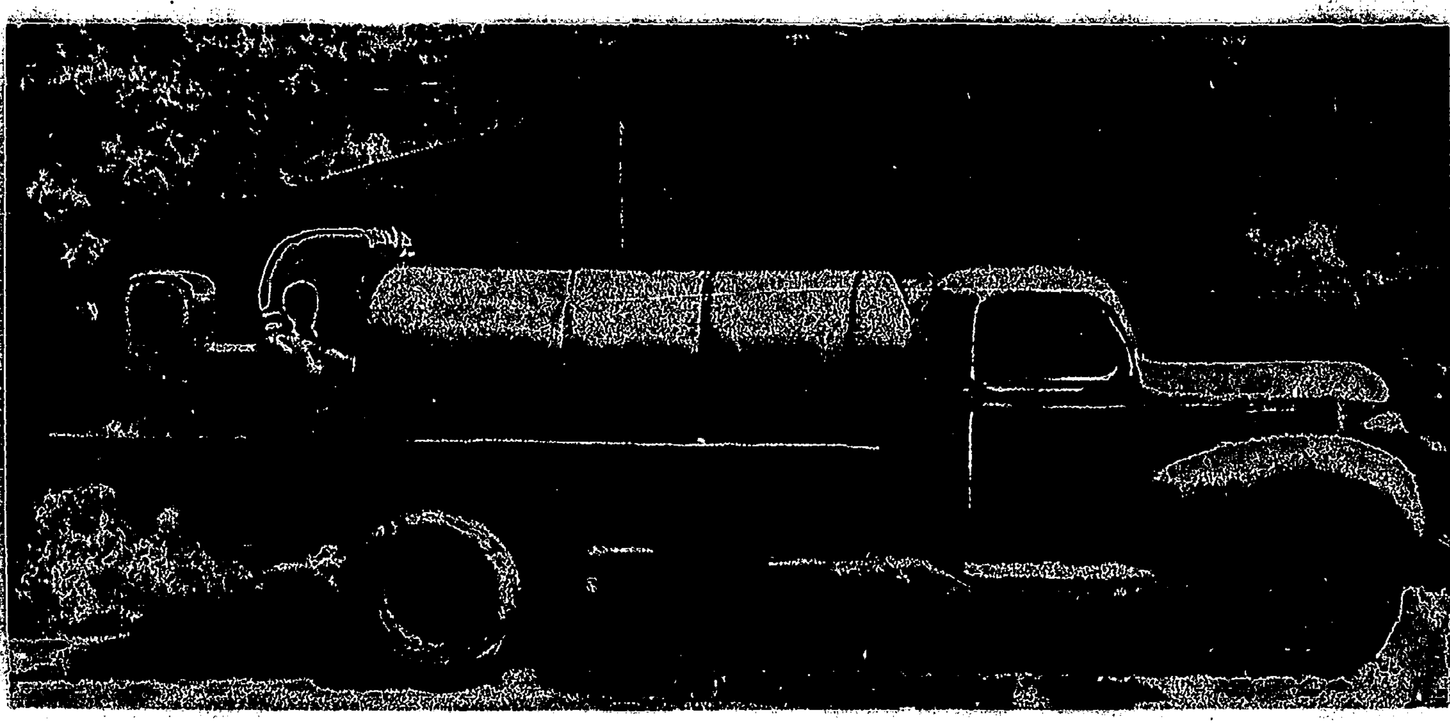
tanks and 6 feet for the larger ones. Manholes should be provided over the inlet and outlet pipes and over the low points in the bottom of hopper-bottom tanks. The roof of the tank may be covered with earth, but access openings should extend at least to the ground surface. Although ells or tees may be used at inlet and outlet connections, straight connections are better for rodding (cleaning out). Instead of ells, wooden baffles, located approximately 18 inches from the ends of the tank and extending 18 inches below and 12 inches above the flow line, are provided. Elevations should permit free flow into and out of the tank. The bottom of the inlet sewer should be at least 3 inches above the water level in the tank. The inlet and outlet connections should be sufficiently buried or otherwise protected to prevent damage by traffic or frost.

Although properly designed septic tanks require little operating attention, they must be inspected periodically, the frequency being determined by the size of the tank and the population load. The minimum frequency should be once every 2 months at periods of high flow. The inspection should be made to assure that the inlet and outlet are free from clogging, that the depth of scum and sludge accumulation is not excessive, and that the effluent passing to subsurface disposal is relatively free from suspended solids. A high concentration of suspended solids in the effluent quickly clogs subsurface disposal facilities. Sludge and scum accumulation should not exceed one-fourth the tank capacity. It should not be assumed that septic tanks liquefy all solids, that they never need cleaning, and that the effluent is pure and free from germs. Perhaps 40 to 60 percent of the suspended solids is retained, and the rest is discharged in the effluent.

Separating sludge and scum from the liquid in septic tanks is difficult; in small tanks these wastes are customarily mixed, the entire contents being removed when the tanks are cleaned. The material removed contains fresh or partially digested sewage solids, which must be disposed of without endangering the health of personnel. Disposal through manholes in the nearest sewerage system, as approved by local authorities, or burial in shallow furrows on open land is recommended. A diaphragm-type sludge pump is best suited for removing the tank contents, which should be transported in a watertight, closed container. Figure 12-20 shows a truck-mounted pump and tank assembled for this purpose.

TILE FIELDS

Tile fields of lines of concrete or clay tile laid in the ground with open joints are used



54.273

Figure 12-20. — Tank and diaphragm-pump assembly for cleaning septic tanks.

to dispose of settled sewage into the ground. A fiber pipe (Orangeburg Alkacid) with holes bored in the lower portion of the pipe to allow drainage may be used for these drain lines. This pipe is light in weight and is easily laid in the trench. It comes in sizes ranging from 2 inches to 8 inches in diameter, and in lengths from 5 feet to 8 feet. Because of these long lengths this type of pipe is particularly valuable in soil where other types may settle unevenly. Figure 12-21 shows a typical field layout.

Proper Functioning

The following conditions are important for proper functioning of the tile fields:

1. Ground water well below the level of the field.
2. Soil of satisfactory leaching characteristics within a few feet of the surface, extending several feet below the tile.
3. Subsurface drainage away from the field.
4. Adequate area.
5. Freedom from possibility of polluting drinking-water supplies, particularly from shallow dug or driven wells in the vicinity.

Tests

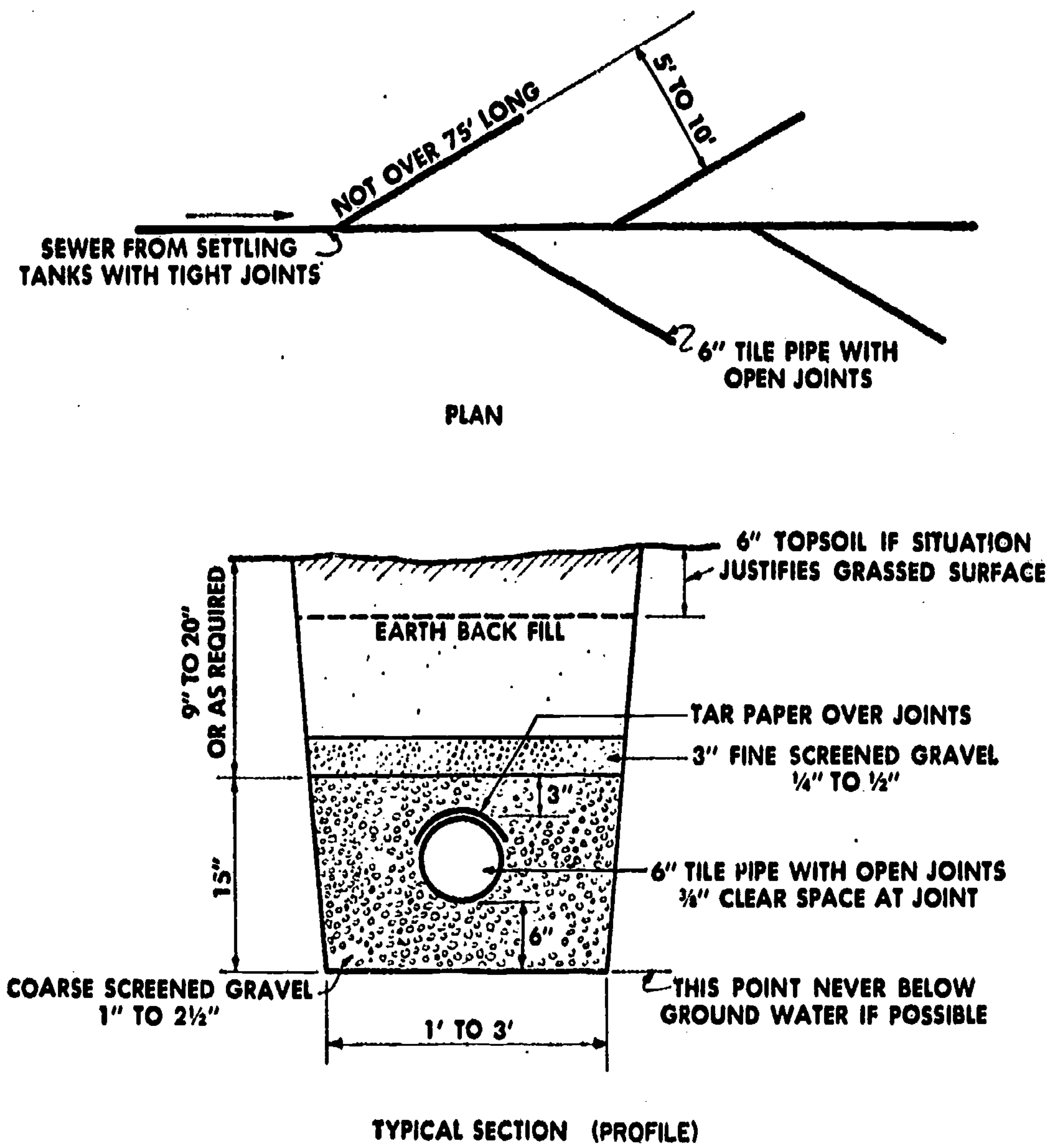
Length of tile and details of the filter trench generally depend upon the character of the soil. Soil leaching tests should be made at the site as described for leaching cesspools, except that the test hole should extend only to the approximate depth at which the tile lines are to be laid. For extensive tile fields, several tests to determine the best location and average conditions should be made. From test results, the rate of sewage application to the total bottom area of the tiled trenches may be taken from the data below. Soil testing over 30 minutes is not suitable.

Time for water to fall 1 inch (minutes)	Allowable rate of sewage application in gallons per square foot per day, bottom of trench in tile field.
1	4.0
2	3.2
5	2.4
10	1.7
30	0.8

Trench Width

Minimum widths of trenches on the basis of soils are as follows:

1. Sand and sandy loam, 1 foot.



54.390

Figure 12-21. — Typical layout of a subsurface tile system.

2. Loam and sand and clay mixture, 2 feet.
3. Clay with some gravel, 3 feet.

Frostline

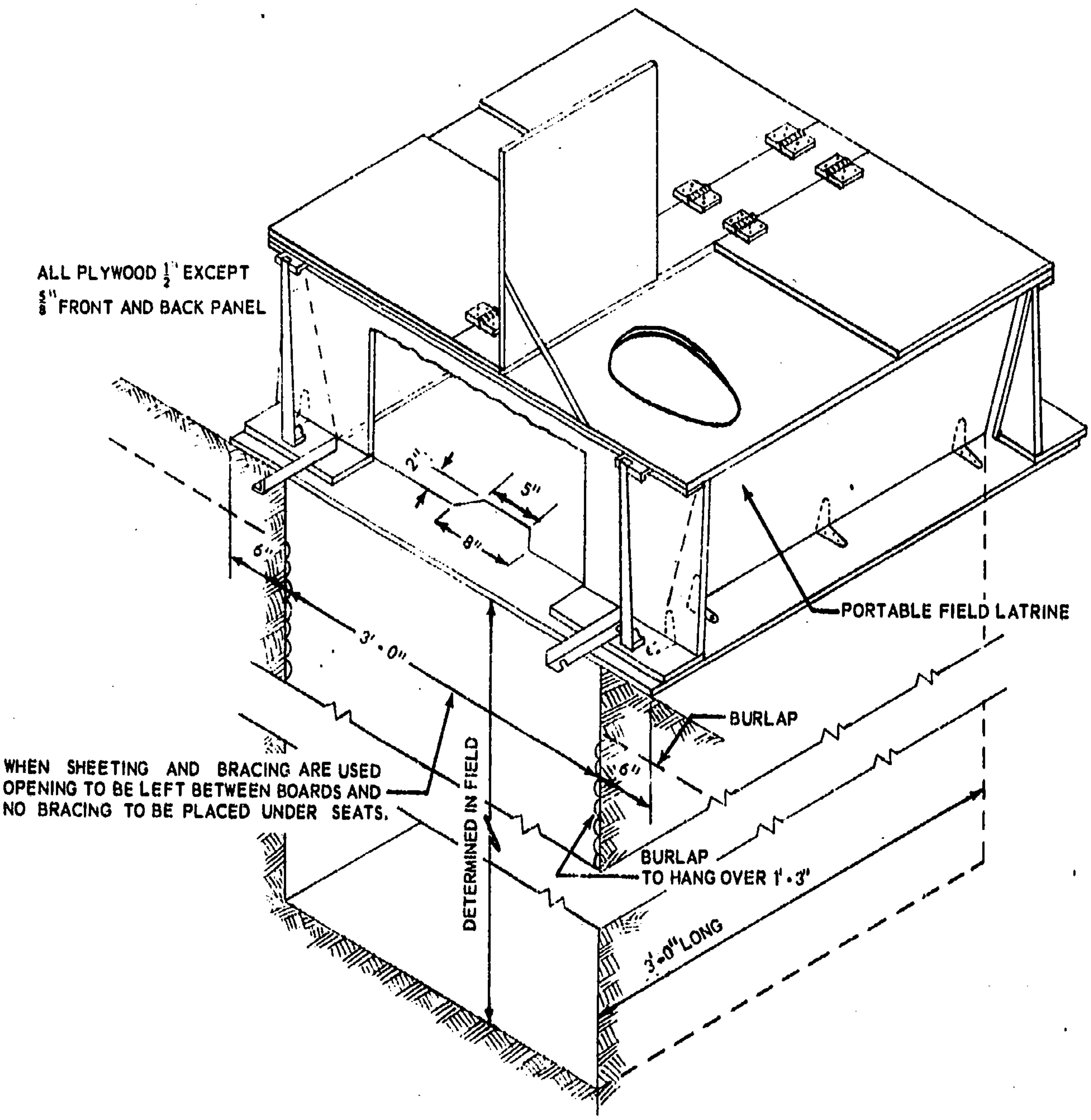
Placing tile below the frostline to prevent freezing is not necessary. Tile placed 18 inches below the ground surface operated sucessfully in New England for many years. Subsurface tile should never be laid below ground water level.

Pipe Size

Design and construction should provide for handling and storage of some solid material, eliminating as much as practicable the opportunity for clogging near pipe joints. Pipe 4 to 6 inches in diameter is recommended. The larger pipe gives greater storage capacity for solids and a larger area at the joint for solids to escape into the surrounding gravel.

Laying the Pipe

To provide for free discharge of solids from the line to the filter trench, the pipe must be laid with 3/8-inch clear openings. The top of the space is covered with tarpaper or similar material to prevent entry of gravel. Bell and spigot pipe is easily laid to true line



133.189

Figure 12-22. — Prefabricated 4-seat latrine box.

and grade. Good practice calls for breaking away two-thirds along the bottom of the bells at the joint and using small woodblock spacers. The pipe is commonly laid at a slope of about 0.5 foot per 100 feet when taking the discharge directly from the septic tank and 0.3 foot per 100 feet when a dosing tank is used ahead of the field.

Beds

The tile is laid on the bed of screened coarse gravel 6 inches deep with 3 inches of coarse gravel around and over the pipe. Coarse screened stone passing 2 1/2-inch mesh and retained on a 3/4-inch mesh is recommended. This gravel bed gives a relatively large percentage of voids into which the solids may pass and collect before the effective leaching area becomes seriously clogged. The soil which fills the trench must not fill the voids in the coarse-screened gravel around the pipe. A 3-inch layer of medium-screened gravel over the coarse stone and 3 inches of either fine-screened gravel or suitable bank-run gravel over the medium stone is recommended.

Layout

The layout of the tile in the field should be carefully designed. Generally, the length of laterals should NOT be greater than 75 feet. When tile is laid in sloping ground, the flow must be distributed so each lateral gets a fair portion. Flow must be prevented from discharging down the slope to the lowest point. Individual lines should be laid nearly parallel to land contours. (See fig. 12-21.) Tile fields are commonly laid out either in a herring-bone pattern or with the laterals at right angles to the main distributor. The distance between laterals is 3 times the width of the trench. Distribution boxes to which the laterals are connected may be desirable. Trenches 24 inches wide or more are economical. If a trenching machine is practical on a large installation, the design should be based on the width of trench excavated by the machine.

Protecting the Field

Once a tile field is constructed, all traffic must be excluded by fencing or posting to prevent crushing the tile. Planting shrubs or trees over the field is not good practice since the roots tend to clog the tile lines; grass over the lines aids in removing the moisture and keeping the soil open. A typical section of a tile filter trench is shown in figure 12-21.

FIELD-TYPE LATRINES

Upon arrival at an advanced base, temporary facilities must be provided immediately for the disposal of human wastes. A number of designs of field-type latrines are used for this purpose. A 16' x 32' wood-frame tent may be used to shelter the field-type latrine.

A prefabricated 4-seat latrine box is illustrated in figure 12-22. This box can be collapsed for shipment as indicated in figure 12-23.

A plan view of an 8-seat field-type latrine is shown in figure 12-24. With this type, two 4-seat boxes are placed so as to straddle a 3' x 7' pit. After the pit is dug, and before the boxes are placed, a 4' wide margin around the pit is excavated to a depth of 6", as shown in figure 12-25. A layer of oil-soaked burlap is laid in this excavation, after which the excavated earth is soaked with oil, replaced, and tamped down, to keep out surface water.

Two 4'6" trough-type urinals are furnished with the 8-seat latrine. Each urinal is mounted in a frame constructed as shown in figure 12-26. A 2" urinal drain pipe leads from the down

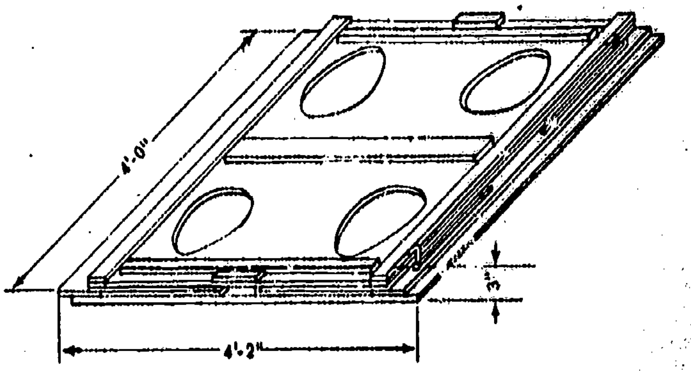


Figure 12-23. — Latrine box collapsed for shipment. 133.190

pipe on each urinal to a 6' x 6' urinal SEEPAGE PIT, located as shown in figure 12-24. The seepage pit is constructed as shown in figure 12-27.

As indicated in figure 12-24, the 8-seat field-type latrine can be expanded to a 16-seat latrine.

A complete plan view of a 4-hole burn out field-type latrine is shown in figure 12-28. This type latrine is used at most advanced or temporary bases. The burn out latrine is kept in an orderly condition (daily) by the camp maintenance personnel or an assigned sanitation crew. Two men can effectively and efficiently dispose of the excremental waste of 500 persons. There are two easy ways of maintaining the burn out latrine; they are: by spreading lime over the waste material, or by using diesel fuel to burn the waste material. The burning pit for the waste material should be located so that resulting smoke, fumes, odors, and blowing ashes will not interfere with any operations or the health and well-being of personnel.

SECONDARY TREATMENT

In addition to primary treatment, sewage, at very large treatment facilities, undergoes further treatment known as secondary treatment. This treatment aims at the oxidation of the sewage solids that have already been treated and are now soluble or finely divided. The following four secondary treatment processes are discussed briefly below: (1) filtration, (2) secondary settling, (3) activated sludge, and (4) contact aeration. The use of oxygen is the major difference between the primary treatment of separating and treating solids and the secondary treatment processes.

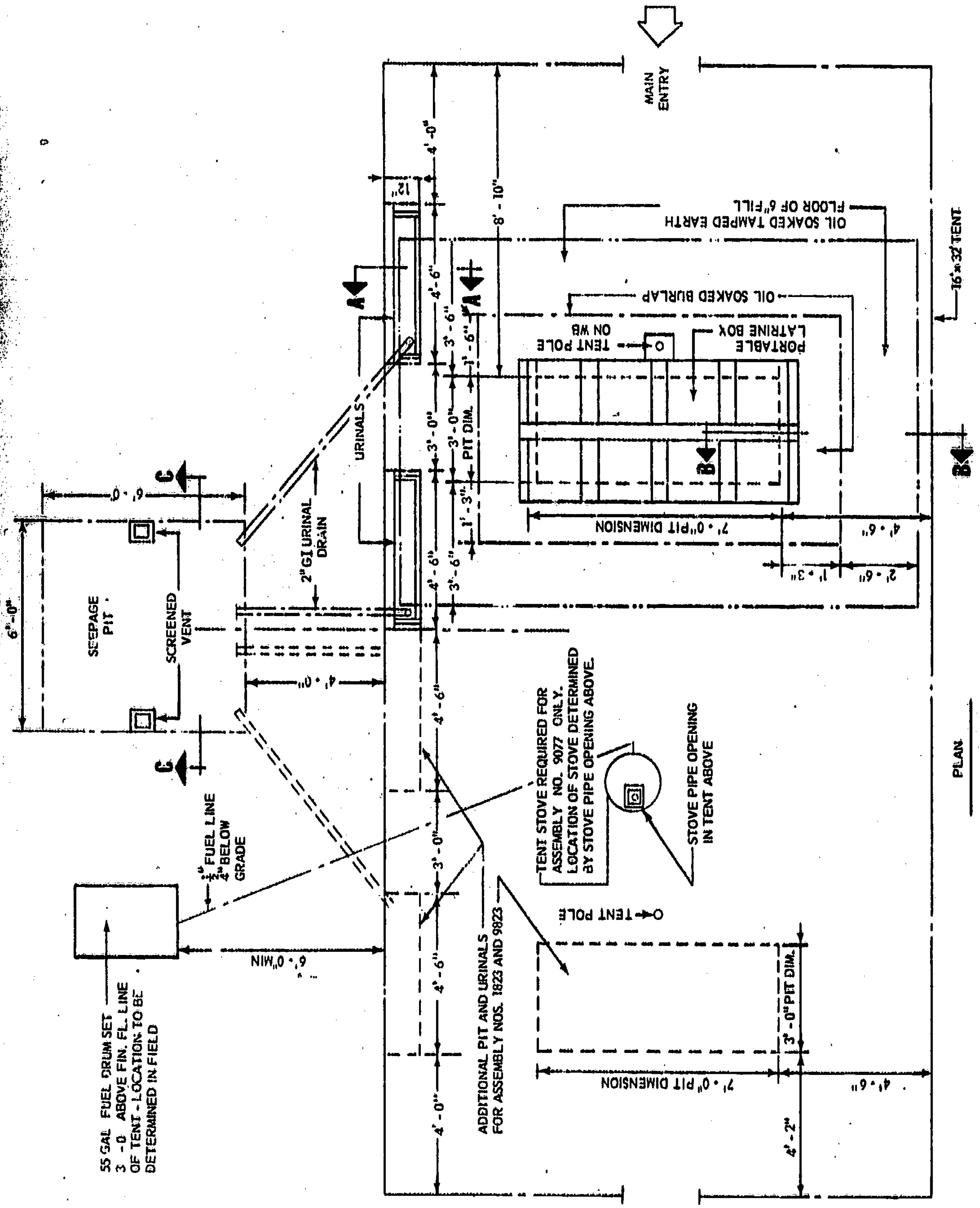


Figure 12-24.—Plan view of 8-seat field-type latrine.

133.191

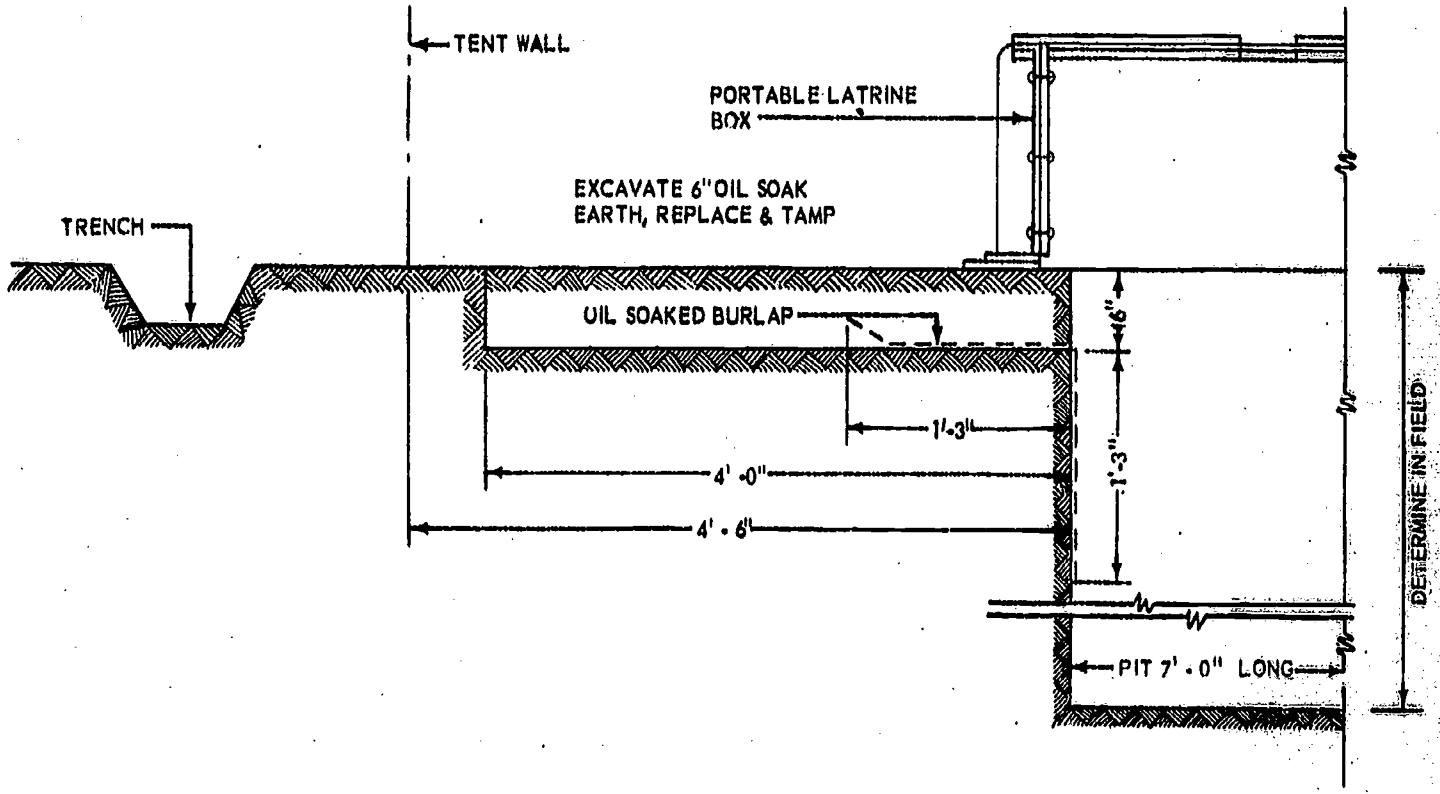


Figure 12-25.—Margin of oil-soaked earth around latrine boxes. 133.192

FILTRATION

The trickling filter—sometimes called trickle, percolating, or sprinkling filter—is the most common secondary treatment unit used in separating solids. The filter is an artificial bed of stone or slag 3 to 8 feet deep, held by a structure of concrete, brick, masonry, or wood. (See fig. 12-29.) The settled sewage is sprayed intermittently at set intervals on the top of the stones. It spreads over the stones and trickles down through the bed to be carried away in underdrains. The floor of the filter is usually made of concrete and supports and contains the underdrains. Air throughout the bed is provided at all times by openings in the walls or vent pipes which carry air from above the surface into the depths of the bed. The sewage is distributed over the top of the filter by spraying nozzles or by movable distributors.

The rough, broken stones attract the solids in the sewage and a gelatinous film develops. As the other sewage passes through, the film retains a lot of the organic matter and it is oxidized. The suspended matter will, from time to time, slip off the rocks and be carried away. This is called unloading and occurs periodically, especially in the spring and fall of the year.

In some cases the sewage is filtered through sand following primary settling or other treatment. The sand filter also serves as a method for the disposal whereby the sewage passes into the ground water and there is no surface effluent. The filter removes suspended solids mechanically by straining and also oxidizes them by action of bacterial films on the sand grains.

If a clean quartz sand area is available, it may be used as a filter bed. Otherwise sand is placed from 2 to 4 feet in depth in a rectangular or square bed. Lateral underdrains are placed on the bottom of the filter or in shallow trenches in the floor.

The sewage is applied at a relatively rapid rate for a short period of time. It is distributed from a temporary storing space called a dosing tank. It goes through troughs which have openings at several points. These troughs are laid on the filter beds.

The dosage varies from 1 dose every other day to 3 doses daily. The bed must drain thoroughly and the flow in the underdrains must be very low before the filter is used again. This is to permit thorough bed aeration.

SECONDARY SETTLING

In some plants, the sewage goes from the trickling filters through secondary sedimenta-

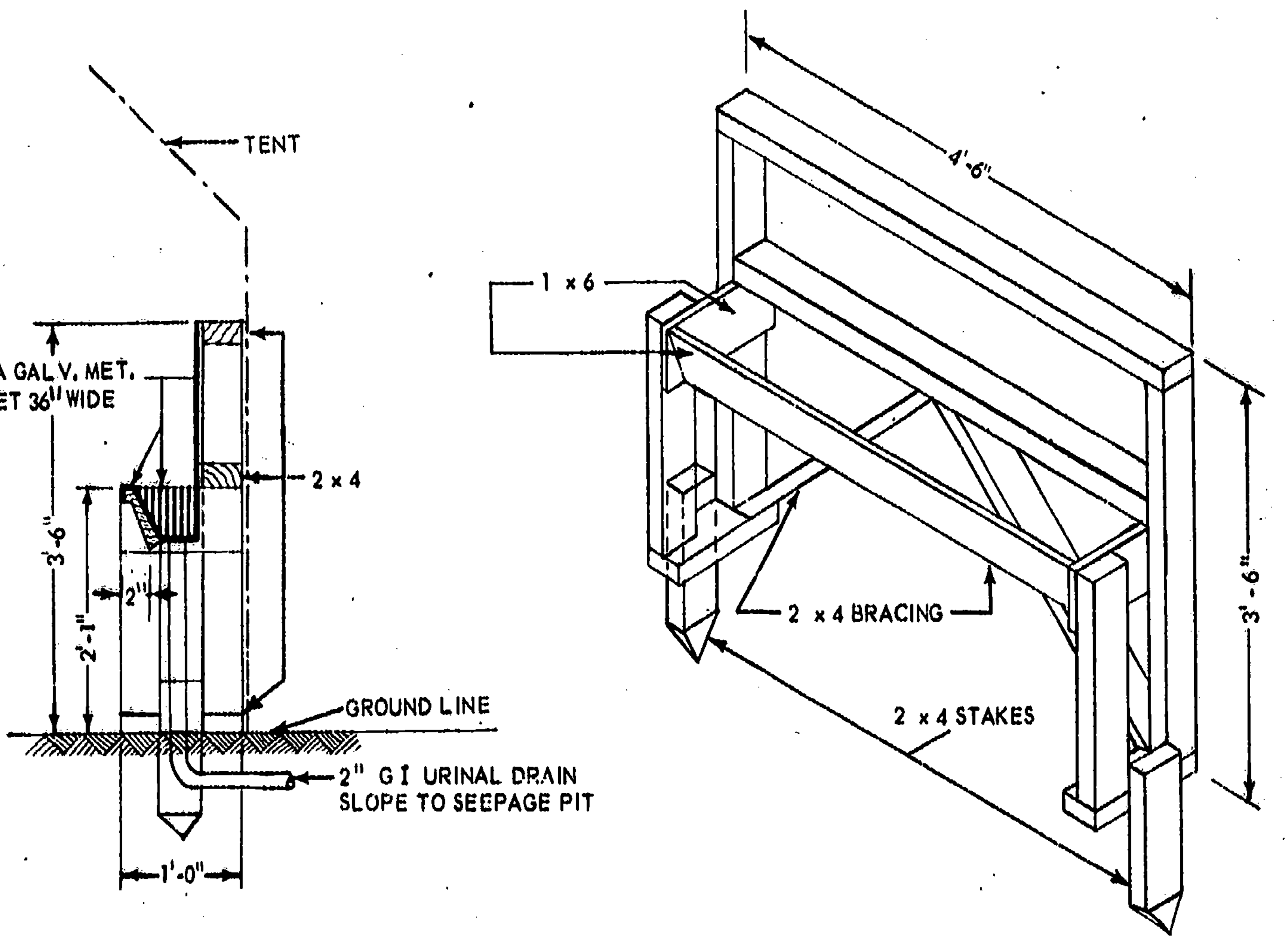


Figure 12-26. — Frame for urinal trough. 133.193

tion tanks. These tanks are similar to the primary plain sedimentation tanks, except that they are usually more shallow. They are operated in the same manner. The sludge from the tanks is disposed of with the sludge from the primary tanks.

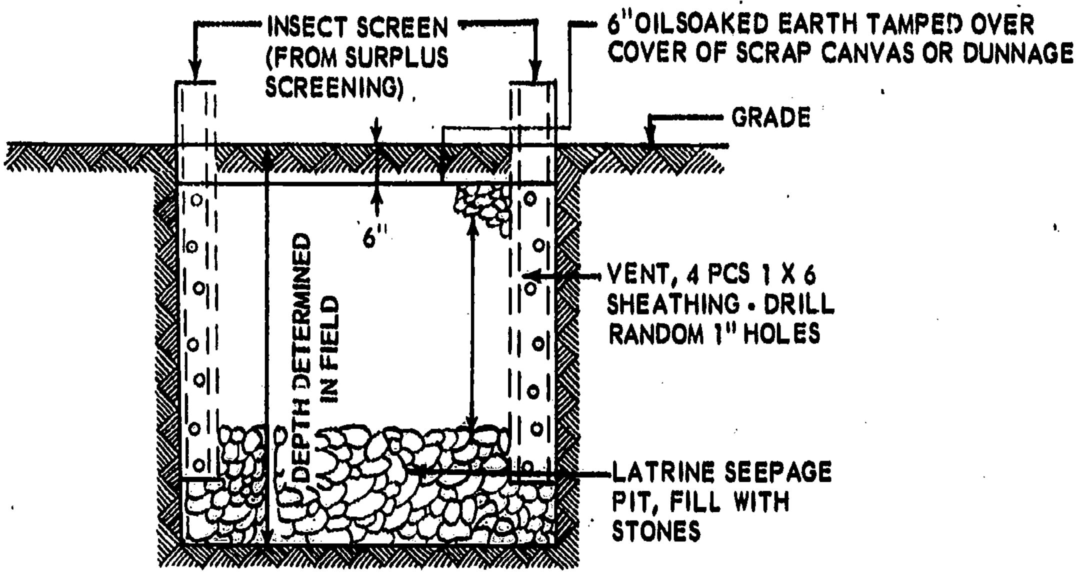
ACTIVATED SLUDGE

Another secondary treatment to remove and treat suspended solids is the activated sludge process. Activated sludge is developed by continuously agitating sewage in the presence of oxygen. It becomes an active biological material composed of numerous organisms. Activated sludge absorbs dissolved organic material and also frees sewage from its dissolved and suspended impurities. Most important of all, it produces organic substances called enzymes, which change objectionable matter to more stable substances.

In this process the sewage receives primary settling and then is mixed with activated sludge to form a mixed liquor. It next receives prolonged aeration in an aeration tank. In some sewage treatment facilities, compressed air is admitted through diffuser plates or tubes in these tanks.

In other facilities, mechanical aerators use impellers, revolving disks, or brushes for spraying sewage into the air or for pulling air down into the sewage. A period of 8 hours is desirable for diffused aeration, and 12 hours for mechanical aeration.

After this, the mixed liquor goes to a final-settling tank. The solids settle at the bottom and filter the sewage as it passes through. This process will remove 90 to 95 percent of the suspended solids. The liquid is usually discharged without further treatment. The sludge at the bottom of the tank contains a larger proportion of nitrogen and has a greater fertilizing value than that produced by any other form of



133.194

Figure 12-27.—Urinal seepage pit.

tank treatment. Some of it is returned to the mixing channel for use with raw sewage.

CONTACT AERATION

Another method of oxidizing and separating the solids is contact aeration. This process is comparable to the trickling filter treatment. The sewage is brought into contact with stationary cement-asbestos plates on which a biological film develops. Air is blown through the contact section from a perforated pipe mounted below the plates.

Sludge is removed from contact aerators about once every 4 hours and returned to the raw sewage flow. The sewage goes on from the contact-aeration tanks to settling tanks.

DISPOSAL

In some instances the final effluent is aerated before it goes to disposal. This is usually accomplished by passing the effluent down an outdoor step aerator.

The common method of disposal is to send the treated sewage through surface or submerged pipes into a stream or other body of water. This dilutes the sewage.

If a stream is unavailable, disposal on land may be done by sending the sewage into a dry stream bed or into an irrigation ditch. Sometimes oxidation ponds or lagoons are utilized.

The oxidation pond or lagoon is a scientifically constructed pond, usually 3 to 5 feet deep, in which sunlight, algae, and oxygen interact to restore water to a quality that is often equal to, or better than, effluent from secondary treatment.

OPERATING RECORDS AND REPORTS

The UT assigned to a sewage treatment facility will have to maintain various records and reports. If maximum benefits are to be achieved, your records and reports should be neat, accurate, and up-to-date.

Operating records are used to show various types of information, such as daily sewage flow, quantity of pumped sludge, temperature, and rainfall. If your plant has a laboratory, operating records should also be maintained to show routine laboratory tests, amount of chemicals, and so on.

From daily records (logs), charts and graphs can be prepared to show at a glance the overall performance of the facility from year to year, as well as the performance of the operating personnel. By using the information from these, the chief in charge can readily see how to improve the performance of both and will have an idea as to when training programs for personnel are needed.

CHLORINATION

Chlorine is used at sewage treatment facilities to control odors, to facilitate treatment, and to disinfect the final effluents. The principles involved in the chlorination of sewage are the same as those in water chlorination.

In the sewage treatment process, liquid chlorine, sodium hypochlorite, or other approved form of chlorine may be used as the disinfectant. Careful attention to proper operating and maintenance conditions is important. Where gas chlorine is used, the temperature in the chlorinating room must be maintained at approximately 70° F. The chlorinator and gasline cannot be exposed to cold drafts from open windows or doors. The chlorine cylinders must not be placed near heaters or in direct sunlight. The chlorine gasline must be kept high, with a constant slope upward from the cylinder to the chlorinator.

Remember that the rate of chlorine withdrawal from each 150-pound cylinder must not exceed 35 pounds for 24 hours. This is to prevent excessive cooling and pressure reduction in the cylinders. If this rate is to be exceeded, connect two or more cylinders in a parallel line. The amounts drawn from a 1-ton container may be as high as 400 pounds per day.

The manufacturer's instructions are usually very complete and must be closely followed in the operation of chlorination equipment. A copy should always be available at the sewage treatment facility.

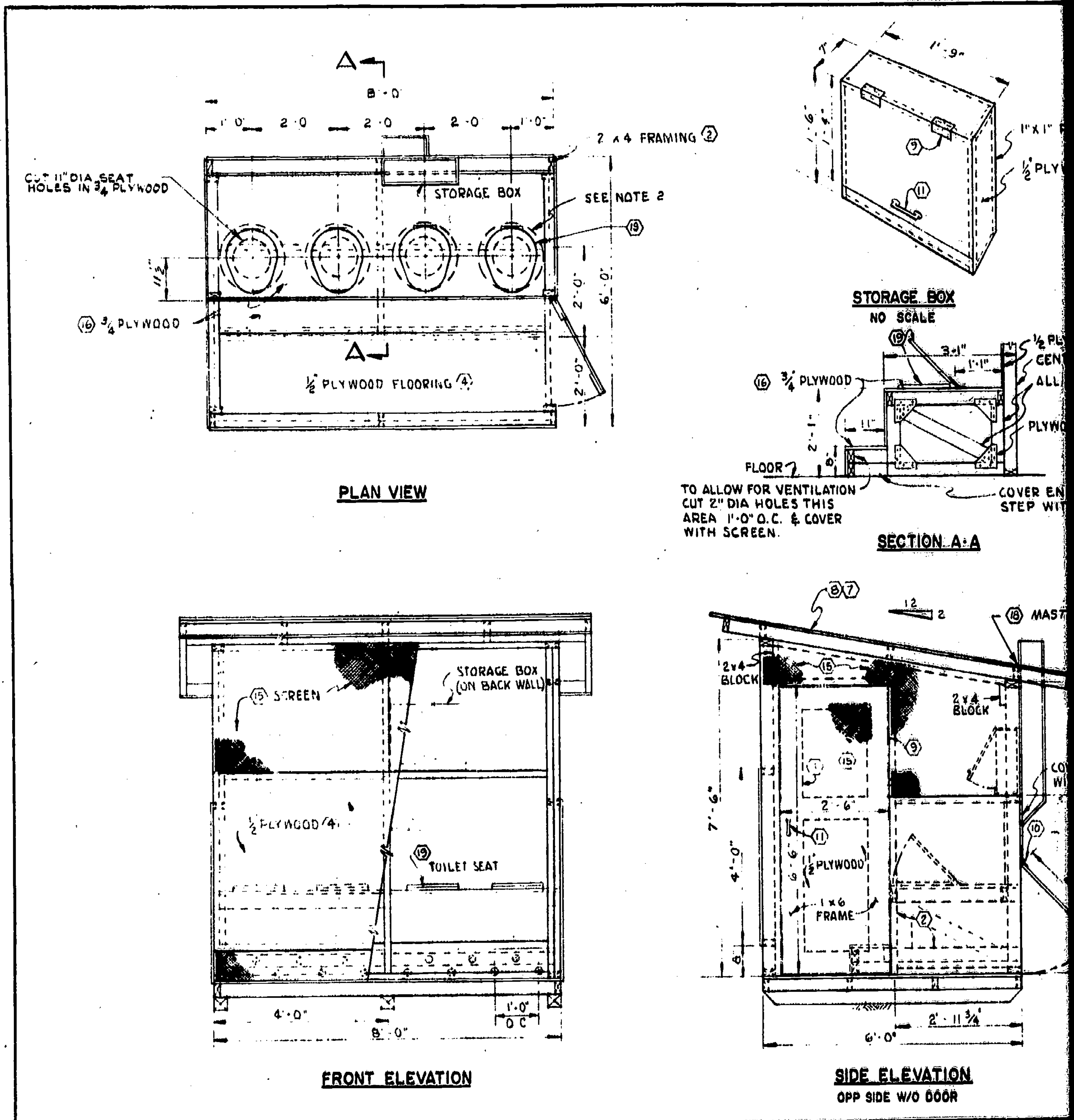
At times, you may be called upon to inspect the chlorinator and all piping for chlorine or water leaks. To locate a chlorine leak, hold the mouth of an ammonia-water bottle, preferably an aspirator type, near all joints, valves, and along the piping. White fumes of ammonium chloride indicate a leak. Take necessary action to correct leaks immediately, since the size of chlorine leaks increase rapidly and result in the corrosion and destruction of equipment. Keep the ammonia bottle tightly stoppered when not in use to prevent a loss of strength. Use litharge and glycerin cements in making metal screwed-pipe connections.

Since chlorine is poisonous, precautions must be taken to protect personnel. Operators should be trained in the proper use of protective equipment such as self-generating oxygen breathing apparatus and self-contained oxygen breathing apparatus, and the methods of stopping leaks. Adequate ventilation should be provided in the chlorinator room. Since chlorine gas is heavier than air, ventilation must be done by fans or blowers at the floor level and must be adequate to displace the air in the room within a few minutes. If forced ventilation cannot be provided, place ventilating louvers at floor level. Keep two sets of protective equipment, suitable for chlorine protection, outside the chlorinator room. It is important that personnel be instructed in the proper use of the protective equipment. Renew the canister at designated intervals. Never enter a room in which chlorine is leaking, unless provided with protective equipment. Where chlorine gas is excessive, enter the room only with a mask supplied with air from the outside. Station one person outside to assist in case of an accident. Reduce the amount of chlorine in a room by liberally spraying with water. One way to relieve irritation resulting from chlorine inhalation is by inhaling fumes from a pan of hot water to which 6 to 10 drops of tincture of benzoin have been added. This relieves the victim until medical aid can be obtained. You may recall that additional safety precautions applicable to chlorine are contained in earlier chapters of this training manual concerning plants and maintenance of water treatment plant equipment; if necessary, go back and review those precautions as part of this instruction.

SAFETY

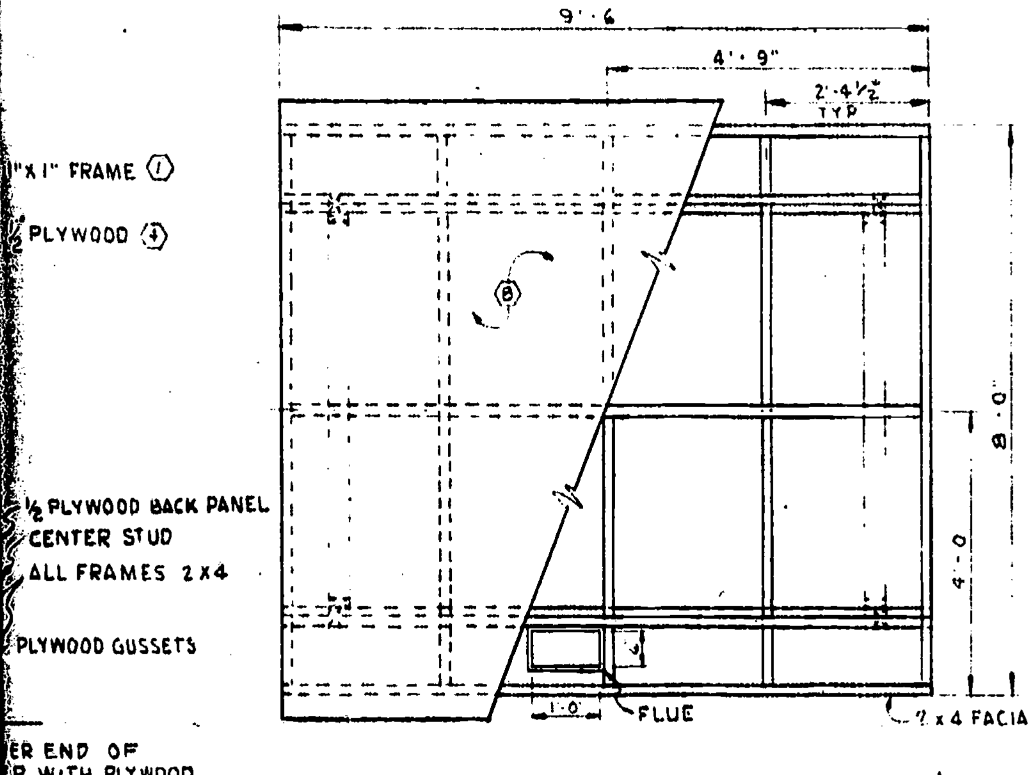
Safety should be a matter of chief concern to all personnel assigned to the sewage treatment facility. Various safety precautions pointed out in the chapter on maintenance of water treatment plant equipment are applicable to both the water treatment plant and the sewage treatment facility. Some additional precautions that should be carefully observed by sewage treatment facility personnel are given below.

Good housekeeping is important at the sewage treatment facility. Tools should be returned to their proper place when you have finished using them on a job. See that manhole covers are promptly replaced and that walkways are kept free from greases and oil. The sidewalks of influent and effluent channels, baffles, weirs, launders, and tanks should be kept clean by hosing, scraping, or brushing. Channels must be kept free of solids. Dead ends and corners must be brushed, and all accumulations removed. Icy walks should be covered with sand.

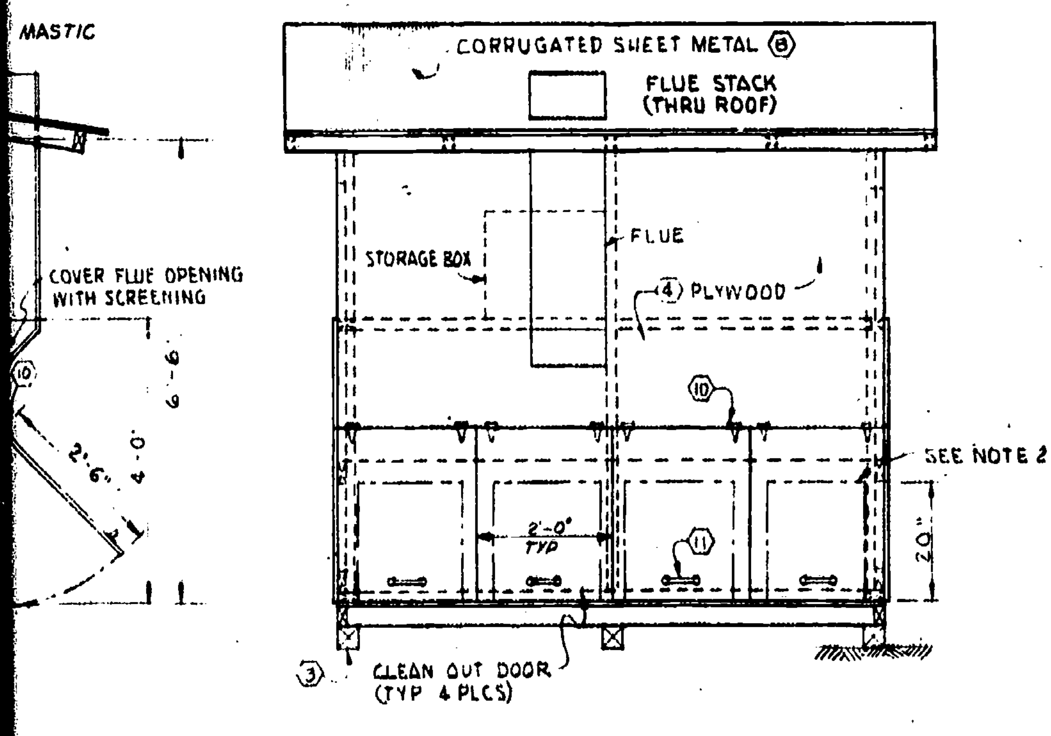


CUT 11" DIA SEAT HOLES IN 3/4 PLYWOOD
STORAGE BOX
SEE NOTE 2
2 x 4 FRAMING (2)
(16) 3/4 PLYWOOD
1/2 PLYWOOD FLOORING (4)
PLAN VIEW
STORAGE BOX
NO SCALE
(16) 3/4 PLYWOOD
FLOOR
TO ALLOW FOR VENTILATION CUT 2" DIA HOLES THIS AREA 1'-0" O.C. & COVER WITH SCREEN.
SECTION A-A
(15) SCREEN
STORAGE BOX (ON BACK WALL)
1/2 PLYWOOD (4)
(19) TOILET SEAT
FRONT ELEVATION
2x4 BLOCK
2x4 BLOCK
1/2 PLYWOOD
1x6 FRAME
SIDE ELEVATION
OPP SIDE W/O DOOR

336



ROOF FRAME DETAIL



REAR ELEVATION

BILL OF MATERIAL

ITEM	DESCRIPTION	UNIT	ASSEMBLY	QUAN.	ZONE
	HEAD, FOUR HOLE		1156		
(1)	LUMBER 1 X 6 X 16'	BF		25	
(2)	LUMBER 2 X 4 X 12'	BF		480	
(3)	LUMBER 4 X 4 X 12'	BF		32	
(4)	PLYWOOD 1/2 x 48 x 96	SH		10	
5	NAILS 8D COMM	LB		10	
6	NAILS 16D COMM	LB		5	
(7)	NAILS W/NEOP WASHER 5 LB	PG		1	
(8)	CORR SHT MTL 27 1/2 x 96"	SH		5	
(9)	HINGE BUTT 3 1/2"	PR		2	
(10)	HINGE TEE 3"	PR		8	
(11)	DOOR PULL	EA		6	
12	SPRING DOOR 9"	EA		1	
13	STAPLE TACKER, 3/8	[illegible]		1	
14	PLASTIC CEMENT 50 LB DR	[illegible]		1	
(15)	SCREEN INSECT 48"	RO		20	
(16)	PLYWOOD 3/4 x 48 x 96	EA		1	
17	STEEL BAR REINF 3/8	FT		6	
18	CALKING COMPOUND	CN		1	
19	SEAT, WATER CLOSET	EA		4	

NOTES:

1. HEX SYMBOL ON BILL OF MATERIAL IDENTIFIES ITEM SHOWN ON DRAWING.
2. CUT SURPLUS DRUMS 18" HIGH AND WELD HANDLES USING ITEM 17.
3. DRAWING DEVELOPED PER INFORMATION 3RD NCB DRAWING 67-STD-D-6CO1.

SYM	DESCRIPTION	BY	DATE	APPD

REVISIONS

FUNCTIONAL COMPONENT ASSEMBLY NO. 1156

DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING COMMAND

MATERIEL DEPARTMENT

U. S. NAVAL CONSTRUCTION BATTALION CENTER PORT HUENEME, CALIFORNIA

	ARCH	ELEC	MECH
DSGN	R.G.		
DRW	BJ HEINAUER 9-11-68		
CHK	J.A.		

PROJ DIR

SUPTG SECT

DSGN SECT

ENGRG BR

DIV DIR

ADVANCED BASE

HEAD

BURN OUT TYPE

FOUR HOLE

APPROVED

FOR COMMANDER NAVFAC DATE

SATISFACTORY TO

DATE ______ BY ______

SCALE 3/4" = 1'-0" SK. NO. 68232

SH. ___ OF ___

NAVFAC DRAWING NO. 1109837

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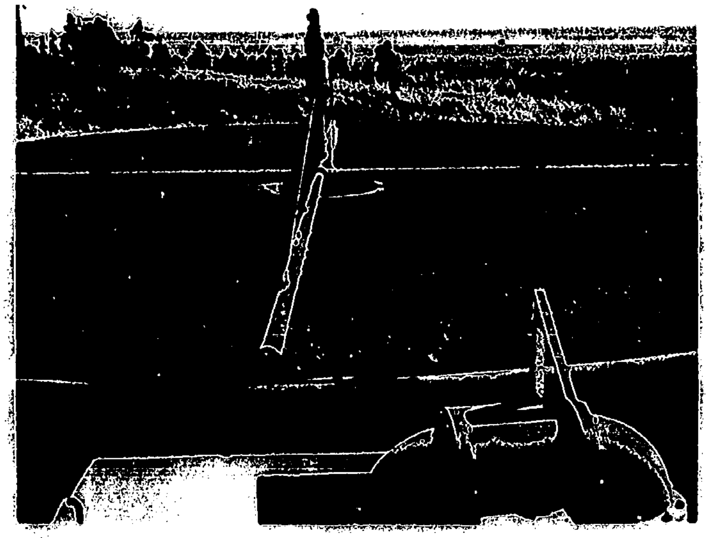
133,391

Figure 12-28. — 4-hole burn out field-type latrine.



54.112
Figure 12-29.—Trickling filter.

Sewage treatment facility workers should never smoke, drop lighted matches, burn tobacco, or use open flames (such as pavement asphalt heaters) in or around sewers, screen chambers, sludge digesters, or sewage settling tanks. An ignition spark can even be created while removing manhole covers.

Wearing coveralls, or a complete change to work clothes, is recommended during working hours.

Workers in sewage treatment facilities and sewage pumping stations should wear rubber (synthetic type) gloves to prevent infection while cleaning clogged sludge pumps, and while handling screenings, sewage grit, or other filth. Glove protection is particularly important when the hands are chapped or burned, or the skin broken from any wound.

It is always wise to avoid actual contact of the hands with sewage, sludge, or other filth. Hands must be kept out of the nose, mouth, and eyes. Before eating, hands should be washed thoroughly with plenty of soap and hot water. The fingernails should be kept short and foreign matter removed with a knife, nail file, or stiff soapy brush. Contaminated ends of cigarettes or cigars, or smoking pipes also may introduce infectious material into the mouth.

Rubbers or boots should be worn to keep the feet clean and dry while doing sludge pumping and other chores. And, personnel entering deep sewers, where removal in case of injury would prove difficult, should always wear a safety belt and lifeline.

Permissible electric explosion-proof lights or flashlights should be used in deep, dark manhole shafts to prevent physical injuries.

Portable blowers equipped with vapor-proof, totally-enclosed motors or non-sparking gas engines should be used when ventilation of tanks, pits, and manholes is necessary. When employed they should be placed on the leeward side of the manhole and not less than 6 feet from the opening. Compressed-air-driven equipment is also safe for use in such locations. When needed, ventilation should be continued in operation while the work progresses, and tests for the presence of dangerous gases or oxygen deficiency should be made at intervals during the time, as well as before, the work is done.

If illumination is required in sewers, pumping station receiving wells, or tanks where flammable gases may be present, permissible electric cap lamps should be worn if available. Approved explosion-proof flashlights and extension electric lights with heavily insulated cords may be used.

Warning signs should be installed near dangerous machinery and blind obstructions, and for any hazardous locations where stumbling may occur.

Warning signs, properly placed, should be used to ban all smoking and open lights in the vicinity of sludge tanks, septic tanks, and sewage conditioning bins. Signs warning against open flames should also be used in sludge digestion tank galleries and in rooms where sludge gas piping and safety devices are located.

When a manhole is opened, a man with a red flag or a red lantern should be assigned as a guard to warn pedestrians and vehicular traffic. Barricades with suitable warning signs (such as DANGER, MEN WORKING, OPEN MANHOLE, etc.) should be erected around the manholes. At night, open manholes must be protected with four red lanterns placed about 20 feet away from each other around the manhole in a square formation, with one of the lanterns located about 10 feet ahead of the opening so as to be easily discernible by approaching traffic.

A manhole cage over the shaft should be provided for protection to the workmen in the sewer because it affords them a handhold in descending and ascending the manhole shaft.

Workmen descending a manhole shaft to inspect or clean sewers should try each ladder step or rung carefully before putting their full weight on it to guard against insecure fastening due to corrosion of the rung at the manhole wall.

When work is going on in deep sewers at least two men should be available for lifting workers from the manhole in the event of serious injury.

When entering a large or deep sewer or underground structure where dangerous gas or an oxygen deficiency may be present, sewer maintenance crews must follow these procedures:

1. Do not allow smoking or open flames, and guard against sparks.
2. Erect warning signs.
3. Use only safety gas-proof electric lighting equipment.
4. Test the atmosphere for noxious gases and oxygen deficiency.
5. If the atmosphere is normal, allow workmen to enter with a safety belt attached and with two men available at the top. For extended jobs, the gas tests should be repeated at frequent intervals, depending on circumstances.
6. If oxygen deficiency or gas is found, ventilate the structure with pure air by natural or artificial means. The gas tests should be repeated and the atmosphere cleared before entering. Adequate ventilation must be maintained during this work, and the tests frequently repeated.
7. If gas or oxygen deficiency is present and it is not practical to ventilate adequately before workers enter, use a hose mask and take extreme care to avoid all sources of ignition. Workers should be taught how to use the hose equipment. In these cases they should always use permissible safety lights (not ordinary flashlights) and wear rubber boots or nonsparking shoes.

Work in flammable gas atmospheres is extremely hazardous; it should never be attempted except by those thoroughly familiar with the dangers and fully equipped with the proper protective safety equipment.

Before entering a digester tank which has been emptied, make sure that it has been purged with live steam or CO_2 and then thoroughly ventilated.

When purging sludge gas holders, the bottom entrance manhole cover should be removed and the gas vented to the atmosphere through all available openings in the top. All sources of possible ignition for the gas mixture should be carefully controlled during this operation. A combustible gas indicator should then be employed to check the tank atmosphere before entering.

Cross connections between the drinking water supply and the sewage or sludge piping, or the equipment in sewage treatment facilities and water treatment plants, are prohibited. Continuous diligence must be exercised to avoid making such connections.

Temporary water flushing pipes or hose must not be allowed to remain connected with sewage or sludge pipes or tanks after use.

If you do work in the laboratory, follow safety precautions given in the chapter on quality control in water treatment as applicable.

SEWAGE SAMPLING

Sewage samples are taken and analyses are made for the following reasons:

1. To determine the strength and composition of sewage, permitting the necessary treatment for local requirements.

2. To control the various sewage treatment processes.

3. To determine efficiency of processes and units.

4. To predict effects at the point of final disposal.

5. To determine actual results of treated-sewage discharge.

6. To compile records and data for future use.

Sewage samples must be as nearly representative of the entire body of sewage as possible. Errors in sampling too often nullify the accuracy of laboratory tests. Because of the stratification of solids in conducting channels, rapid changes in the characteristics of sewage caused by intermittent pumping, as well as the diverse characteristics of sewage itself, representative samples are difficult to obtain unless procedures are established and followed carefully. Lack of uniformity in sampling leads to incorrect conclusions about the operation of the treatment process. Analytical results are too often accepted without properly considering the limitations of the sample examined.

GRAB SAMPLES

Grab samples are those taken in a sampling process at any one time from only one point. Such samples cannot give much information about average conditions of the sewage throughout the day, but they show the momentary condition for immediate control purposes. Some tests require grab samples because changes occur rapidly in the samples if the time between sampling and testing is long.

COMPOSITE SAMPLES

Composite samples are made by gathering individual samples at regular intervals over a selected time period, which is usually 16 to 24 hours. The time interval for raw influent sewage, intermediate stage of treatment, or the final effluent is 1 hour, unless special tests or studies are being made. The volume of each single sample is in proportion to the rate of sewage flow as determined by flow meter, Parshall flume, weir, or other measuring device. A set of well-labeled sampling containers, in a range of sufficient sizes to accommodate the normal flow variations, must be prepared. Individual samples of sewage influents and effluents are immediately poured into each separate container large enough to hold the entire amount of the composite sample that is expected over the period (about 1 gallon). These containers are refrigerated, or kept cool. Wide-mouth glass-stoppered bottles or covered enameled pails are used.

SAMPLING PERIODS

The sampling period is preferably 24 hours, but it must cover at least 16 hours except at plants that have a shorter period of attendance. The selection of the period depends on the relative rates of flow during the day. Flow and strength are usually uniformly low for an 8-hour period during the night. For 16-hour plant attendance, two samples, each proportioned to the total flow over a 4-hour period, can be taken in place of the hourly samples for this night flow. These samples are taken both at the beginning and at the end of the period and are mixed with the hourly samples taken during the day to form a 24-hour composite. If the composite-sampling period is less than 16 hours, the length of time is noted on the monthly operating log.

COLLECTING SAMPLES

Sewage samples from channels are taken at two-thirds the depth of the flow at a point free from back eddies and from a tank, just ahead of the overflow weir. Figure 12-30 shows the design of the sampler.

Sampling for dissolved oxygen requires special procedure and apparatus to prevent an increase in the oxygen content through contact with air. Narrow-mouth glass-stoppered bottles should be used with the sampling can.

The design of a sampler for collecting sludge samples from digesters is shown in figure 12-31. The chain is marked to indicate depth at 6-inch intervals. Samples of digester sludge are collected at 3- to 5-foot intervals, starting at the top and working down to avoid agitating the sludge from which the following samples are taken. Each sample is poured into an appropriately marked wide-mouth bottle, and the sampler is thoroughly rinsed before each sample is taken. A pitcher pump with a hose marked at 1-foot intervals may also be used.

Composite sludge samples from raw sludge to digester or digested sludge to beds are made up of individual samples collected at regular intervals over the pumping or drawing period. These intervals are spaced to provide for collecting at least 5 or 6 individual samples over any one period. The composite must include all pumping periods for the entire day.

SEWAGE TESTS

The UT may be called upon to perform various laboratory tests of sewage, as well as take samples of sewage. Some of the tests that you may make are covered below.

TEST FOR SETTLEABLE SOLIDS

The following procedure should be used in testing for settleable solids:

1. Fill an Imhoff cone to the liter mark with the thoroughly mixed sewage sample.
2. Allow sewage to settle for 1 hour and 45 minutes.
3. Stir sample gently with a rod or rotate the cone to cause the solids adhering to the upper sides to settle.
4. Allow sewage to settle 15 minutes more.
5. If large voids occur in the sludge in the cone tip, the sludge may be gently compacted with a rod before the reading is made. Read

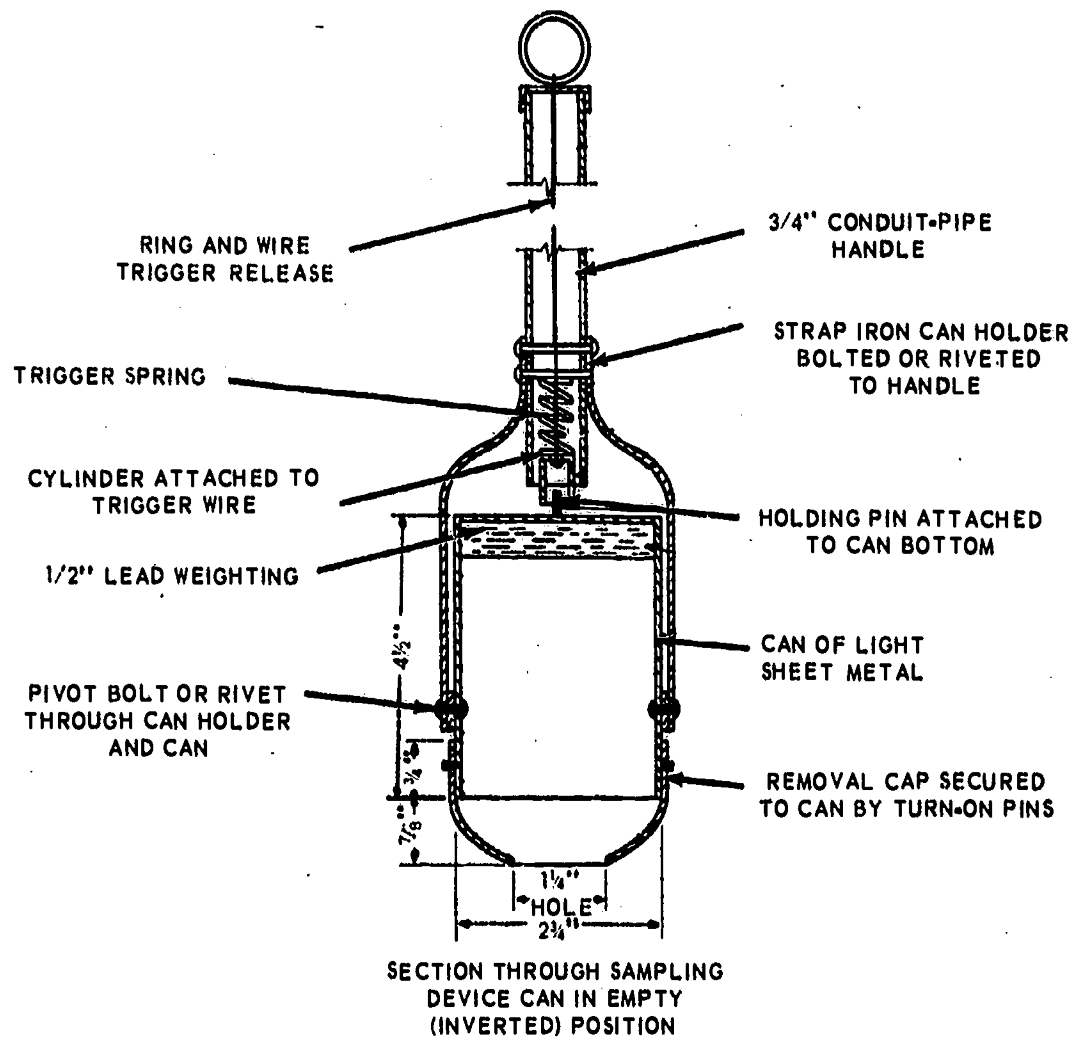


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Figure 12-30. —Sampler for collecting sewage.

the volume of solids settled in the tip of the cone and report as milliliters (ml) of 2-hour settleable solids per liter.

TEST FOR SPECIFIC GRAVITY OF SLUDGE

The following procedure should be utilized to determine the specific gravity of sludge.

1. Weigh (to the nearest 0.1 gram) an empty wide-mouthed flask or bottle of about 250 ml capacity. Weigh the same flask filled completely with distilled water, and again filled completely with the sample.

Calculation:

$$\text{specific gravity} = \frac{\text{weight of sludge (gm)}}{\text{weight of same volume of distilled water (gm)}}.$$

2. Record the specific gravity to the third decimal place.

TEST FOR SUSPENDED AND DISSOLVED SOLIDS

The procedure below should be followed in testing for suspended and dissolved solids by the GOOCH CRUCIBLE METHOD. For this test, asbestos fiber emulsion is used as reagent.

1. Place a Gooch crucible in a suction flask and pour into it about 25 ml of asbestos emulsion.

2. Apply the suction gently until the mat is formed.

3. Wash with distilled water until no fibers of asbestos pass through the filter.

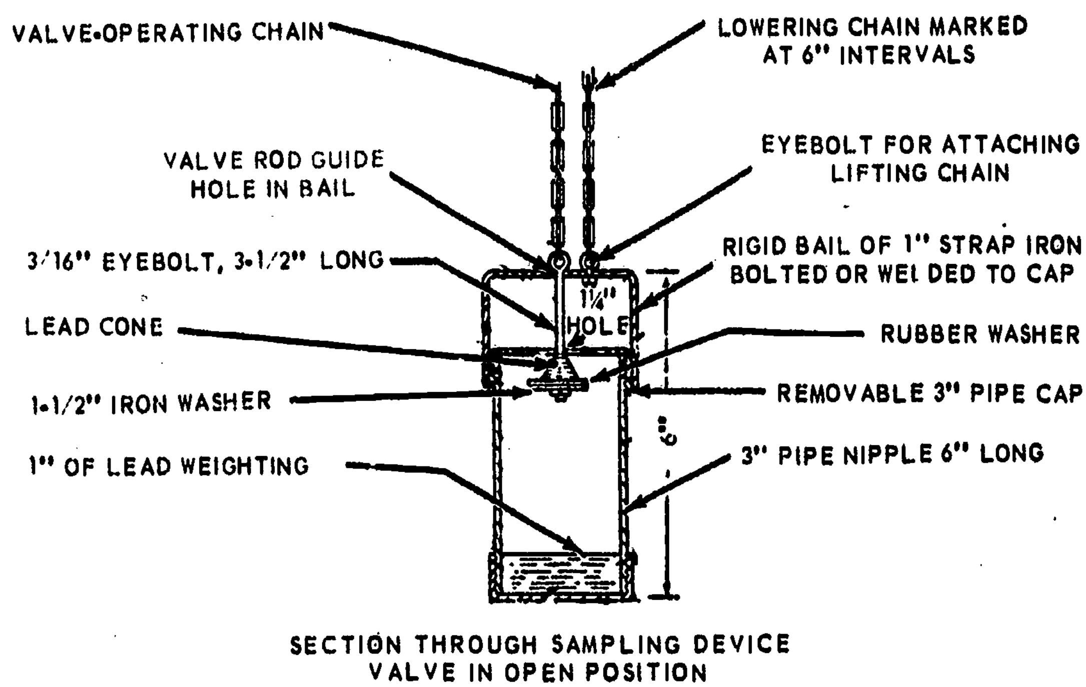

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Figure 12-31. — Sampler for collecting sludge.

4. Dry the crucible in a 103° C oven and ignite, in a muffle furnace or over a burner, at a low red heat.

5. Allow the crucible to cool. Moisten the mat with a few drops of distilled water.

6. Dry in a 103° C oven for 1 hour, cool in a desiccator, and weigh. (Steps 4 and 5 may be omitted if the loss on ignition of suspended solids is not to be determined.)

7. Measure 100 ml (use a larger portion if the suspended matter is low) of the well-mixed water by means of a volumetric flask or pipette.

8. Filter the sample portion through the prepared Gooch crucible and follow with several distilled-water rinsings of the flask. Be sure that all suspended matter has been transferred to the crucible.

9. Dry in the oven at 103° C for 1 hour, cool in the desiccator, and weigh.

Calculations:

$$\frac{\text{Increase in weight (gm)} \times 1{,}000{,}000}{\text{ml of sample}} = \text{ppm suspended solids}$$

$$\text{ppm total solids} - \text{ppm suspended solids} = \text{ppm dissolved solids.}$$

Example:

Sample portion	No. 1
Weight of crucible and solids (500 ml)	15.6208 gm
Weight of crucible	15.5726 gm

Increase in weight = 0.0482 gm

$$\frac{0.0482 \times 1{,}000{,}000}{500} = 96.4 \text{ ppm.}$$

Results may be checked by duplicate samples.

Total solids test of sample	= 442.0 ppm
Suspended solids test of sample	= 96.4 ppm
Dissolved solids	= 345.6 ppm

If you have to prepare asbestos fiber emulsion, place 2.5 grams of finely shredded acid-washed asbestos fiber in a liter bottle. Then add 900 ml of distilled water and shake thoroughly.

TEST FOR TOTAL SOLIDS

The following procedure should be utilized in testing for total solids.

1. Clean a platinum evaporating dish and place it in a 103° C oven for 1 hour or, if the

loss on ignition determination is also to be made, ignite to low red heat in the muffle furnace or over a burner. (A platinum dish is preferred, but other types may be used.)

2. Place the dish in a desiccator until cool, then weigh.

3. Place the weighed dish in a water bath.

4. Thoroughly mix the sample and measure 100 ml (a large volume may be used) by means of a volumetric flask or pipette.

5. Transfer the sample to the dish, rinse the flask or pipette several times with small portions of distilled water, and add the rinsings to the dish. Be sure that all suspended matter is transferred to the dish.

6. After the sample is evaporated, dry the dish and residue in a 103° C oven for 1 hour: cool in the desiccator, and weigh.

Calculations:

Example:

Sample portion:	
Weight of dish and residue (100 ml)	= 48.2982 gm
Weight of dish	= 48.2540 gm
Increase in weight	= 0.0442 gm

ppm total solids =

$$\frac{\text{Increase in weight (gm)} \times 1{,}000{,}000}{\text{ml of sample}}$$

$$= \frac{0.0442 \times 1{,}000{,}000}{100}$$

$$= 442 \text{ ppm}$$

NOTE: Duplicate portions may be checked by adding the sum of the residues and inserting its average in the formula.

ENVIRONMENTAL POLLUTION CONTROL

Environmental pollution is that condition which results from the presence of biological, chemical or physical agents in the air, water or soil which so alter the natural environment that an adverse effect is created on human health or comfort, on animal and plant life, or on structures and equipment to the extent of producing economic loss, impairing recreational opportunity or marring natural beauty.

Pollution poses a potential threat to our natural environment. It causes masonry to crumble, steel to corrode, and skies to darken. It closes beaches and prevents swimming, boating, water-skiing, fishing and other recreational activities. Pollution fills our lakes, streams, and estuaries with debris, scum, foam, oil, garbage, gases, and other loathsome wastes. It contaminates shellfish, destroys game fish, damages vegetation, and poisons waterfowl and other wild creatures. In the future, pollution could adversely affect not only the quality of your environment, but the duration of your life.

Pollution is a matter of prime importance, and it concerns each of us. As a UT there is a lot you can do toward eliminating or controlling water pollution. Background information on the water pollution problem is given in this discussion. Some of the methods used in preventing or controlling water pollution also are covered.

CAUSES OF WATER POLLUTION

Pollution results from many activities, both man's and nature's. Water becomes polluted when wastes from these activities flow into a lake or stream in such quantities that the water's natural ability to cleanse itself is lessened or completely destroyed.

Among the wastes being dumped into our waters every day are some or all of the following:

- Sewage and other wastes from cities and industries, from pleasure boats, commercial ships, and marinas.
- Nutrients (principally phosphates and nitrates) from sewage, industrial wastes, and land run-off.
- Complex chemicals (from household detergents, pesticides and herbicides, wastes from industrial processes).
- Oils from ships, on-land and offshore drill rigs, and shoreline industrial facilities. Crankcase oils from auto service stations.
- Acids from underground and surface mines and industrial processes.
- Silts, sands, debris from city streets, from urban construction, highway building, farm surface erosion, and dredgings from channel clearings.
- Salts from our winter streets, from field irrigation, and from industrial processes.

- Heater water from power projects, industrial processes, and reservoir impoundments.
- Disease-causing bacteria, mainly from municipal sewage.
- Radioactive wastes from mining and processing of radioactive ores, from materials used in power plants and in industrial, medical, and other research, and from fallout during nuclear weapons testing.
- Mercury and other heavy metals from industrial plants.
- Drainage from animal feed lots.

These wastes have placed serious strains on our waste treatment systems, as well as our waterways. Some wastes are very difficult to remove. Others respond to conventional treatment, but we haven't built enough treatment facilities to keep them out of our waters. Solving the pollution problem is not easy but it must be solved, if we are to have an adequate supply of safe, clean water for future use.

HARMFUL EFFECTS OF POLLUTED WATERS

Several basic, biological, chemical, and physical processes affect the quality of water.

Organic wastes (natural products such as food, paper, human waste) decompose by bacterial action. Bacteria attack wastes dumped into rivers and lakes, using up oxygen in the process. Fish and other aquatic life need oxygen. If the waste loads are so great that large amounts of oxygen are spent in their decomposition, certain types of fish can no longer live in that body of water. A pollution-resistant lower order of fish, such as carp, replace the original fish population. The amount of oxygen in a water body is therefore one of the best measures of its ecological health.

If all the oxygen is used, an anaerobic (without air) decomposition process is set in motion with a different mixture of bacteria. Rather than releasing carbon dioxide in the decomposition process, anaerobic decomposition releases methane or hydrogen sulfide. In these highly polluted situations, the river turns dark, and odors—like rotten eggs—penetrate the environment.

Heated water discharged into lakes and rivers often harms aquatic life. Heat accelerates biological and chemical processes, which reduce the ability of a body of water to retain dissolved oxygen and other dissolved gases. Increases in temperature often disrupt the reproduction cycles of fish. By hastening biological processes, heat accelerates the growth of aquatic plants—often algae. Finally, the temperature level determines the types of fish and other aquatic life that can live in any particular body of water. Taken together, these effects of excess heat operate to change the ecology of an area—sometimes drastically and rapidly.

One of the most serious water pollution problems is eutrophication—the "dying of lakes." All lakes go through a natural cycle of euthrophication, but normally it would take thousands of years. In the first stage lakes are deep and have little biological life. Lake Superior is a good example. Over a period of time, nutrients and sediments are added; the lake becomes more biologically productive and shallower. As nutrients continue to be added, large algal blooms grow, fish populations change, and the lake begins to take on undesirable characteristics. After an extended period of time, the lake becomes a swamp and finally a land area.

Man greatly accelerates this process of eutrophication when he adds nutrients to the water—detergents, waste food products, fertilizers, and human wastes. Man's action can, in decades, cause changes that would take nature thousands of years.

Polluted waters have harmful effects on human health as well as on the natural environment. It is true that epidemics of typhoid, dysentery, and salmonellosis borne by polluted water are no longer serious public health threats in the United States. However, to maintain adequate protection of the public from these and other pollution dangers, water must often be treated to high levels before it is drinkable. Beaches often must be closed and shellfish left unharvested and unmarketed. Inadequately disinfected municipal wastes, overflows from combined sewer systems, and runoff from animal feedlots often create high bacteria densities in local water supplies. Ships that are anchored far up-stream can contribute to a high bacteria count in a community's water supply. The Navy is exploring the use of many devices and schemes to lessen the effect of waste discharges in water. Some of them are discussed in the following paragraphs.

Because there have been no constraints on the quality of effluent (nutrients, etc) in the past, optimum damage resistance and minimum cost design for Navy ships dictated a minimum penetration of watertight bulkheads and decks. This led to direct overboard discharge of all waste drains and soil drains into rivers, bays, estuaries, and the high seas at the nearest point of approach of the hull plating from the head or washrooms. Carriers, for example, have as many as 150 discharge hull penetrations.

The Water Quality Improvement Act of 1970, PL 91-224, dated 3 April 1970, stipulates that the Environmental Protection Agency would set the sewage system effluent standards. This law also stipulates that existing ships, including those under construction, would have to be backfitted within 5 years after the sewage system effluent standards were promulgated. Ships constructed after this date must meet the standards within 2 years.

The Navy has funded research and development on Marine sanitation devices. These are: (1) Aerobic Systems, (2) the Macerator-Chlorinator, (3) the Recirculation Flush-sludge Storage System, (4) the 175 Man Fairbanks-Morse System, and (5) the 500 Man Fairbanks-Morse System.

Aerobic systems for shipboard use have not been successful and the Navy terminated this effort several years ago. Both the Coast Guard and the EPA also terminated further development of these basically small extended aeration biological systems for shipboard use.

The Macerator-Chlorinator system merely grinds the solids into small particles and mixes the raw sewage with hypochlorite and some chemical reaction occurs to reduce biochemical oxygen demand (a measure of the amount of oxygen needed to decompose wastes) and most of the organisms are destroyed. This unit is simple to install and operate and is lowest in cost, weight and space problem. Until satisfactory second generation devices are available, the Navy is recommending that EPA consider this device for ships, boats, and service craft having personnel of up to 50.

The Recirculation system uses water to circulate the solid sludge to a holding tank where the water is removed and the concentrated sludge is stored. This system is similar to that used on commercial aircraft. The water is treated by chemicals and is recirculated in the system. The concentrated sludge is cleaned out when the ship is at sea or is connected to a shore sewage line. It is simple, low cost and requires low space and weight for installation. However, holding capacity is limited and this places a constraint on ship operations. One manufacturer of a system of this type is developing an incinerator to burn the sludge.

With all this effort and time, the Navy has yet to develop what can be considered a system that has proven reliable, maintainable and safe. Obviously, ship sewage disposal is the most difficult Navy problem to solve. Currently, many different proposals are under evaluation and we are encountering problems of performance and equipment reliability. The Navy must be absolutely certain that a completely reliable system is available before we start installing equipment on all naval ships.

CONTROLLING WATER POLLUTION

In the fight against pollution, the UT should ensure that cross connections of flushing and sanitary piping systems to fresh water and clean water systems are avoided. Cross connecting flushing and sanitary piping systems with fresh water and clean water systems can introduce disease organisms directly into a water distribution system which can quickly transmit disease to many unsuspecting users or consumers of the water. Even the chloride present in the potable or clean water system may not be adequate to kill all harmful organisms introduced from flushing or sanitary piping.

Cross connections can and do easily occur during repair or alteration of building or underground piping systems where piping is not adequately marked, or where plans and drawings do not accurately show the piping layout. Also, cross connections occur when water-using equipment is connected to existing piping systems or faucets, especially equipment with an onboard pump which could force contaminated water back into the clean water system due to a lower pressure in the clean water system. Care should always be taken when tapping or connecting into existing waterlines. Existing plans or drawings do not always show the true layout; therefore, piping should be thoroughly checked-out to determine its intended use. A single cross connection from a ship contaminated the entire Riverside, California, city water supply system, causing thousands of illnesses and several deaths. Uusally cross connections are not discovered until harmful results, such as sickness or death, create an investigation and search for the cause of the adverse effects.

The most immediate means of limiting or controlling the polluting effect of flushing and sanitary water systems on local water is to assure that all flushing and sanitary water systems that may contain polluting elements are connected to sanitary or industrial sewer systems. This will assure that where adequate sewage treatment plants are available the waste discharge will receive treatment. Many polluting wastes are discharged into storm sewers instead of sanitary sewers. A storm sewer is not connected to a waste treatment plant and usually discharges into the nearest water body or watercourse.

There are some wastes, however, that should never be flushed into any sewer since sewage treatment plants or industrial waste treatment plants are not designed to, nor can they, adequately treat ALL wastes; e.g., wastes containing oils, where there is more than a trace of oil; cleaning fluids, gasoline, or other volatiles; toxic chemicals; acids or alkalies, unless neutralized; and solid materials—to name a few. Such wastes should preferably be handled and disposed of by knowledgeable persons in a non-polluting manner. When in doubt about the pollution potential of a waste, expert assistance should be obtained.

NEED FOR FURTHER STUDY

The above discussion does not attempt to tell you all you need to know about pollution. For additional information, study other books containing material on the subject. Also read magazine articles and various publications dealing with the problems of pollution and methods of eliminating or controlling it. As the fight against pollution continues, the development of new and improved methods and techniques of eliminating or controlling it can be expected. Make sure you keep abreast of those changes that will affect you in your work. And bear in mind that an all-out effort is needed to do something about the pollution problem NOW, else our lives may be drastically affected in the future.

CHAPTER 13

LIQUID FUEL HANDLING AND STORAGE FACILITIES

Petroleum has become increasingly important as a source of light, power and heat. Vast quantities of special petroleum products are essential for use as fuel, as well as for lubricating engines and other equipment. In addition, modern warfare requires many other petroleum products. For example, ordnance equipment must have oil for hydraulic recoil equipment and power drives; petroleum jellies are required for fire bombs; petroleum greases, oil, and waxes are useful for protecting equipment; kerosene is necessary for lighting and heating; and petroleum compounds are needed for sanitation and medicine.

This chapter contains information that will be useful to the Utilitiesman who handles and stores petroleum products. But with space being limited, we can only discuss a few selected pieces of equipment used in or at liquid fuel handling and storage facilities. Information is given on hazards involved in working with petroleum products, and various safety precautions applicable to the handling and storing of petroleum products are pointed out.

LIQUID FUELS

Although fuels and lubricants make up the greatest bulk of military petroleum products, many others are indispensable. The numerous types of petroleum products may be broken down into various major categories, such as liquid fuels, gear lubricants, and greases. Let us emphasize that in this discussion we are primarily interested in only one category—liquid fuels. In this category you have automotive and aviation gasolines, burning oils, and fuel oils.

Automotive gasolines include automotive combat gasoline, all-purpose type, designed for temperatures down to 0° F; all-purpose gasoline designed for temperatures consistently below 0° F; unleaded gasoline with good storage stability; and Motor Fuel M, which may be regular or premium grade.

Aviation gasolines include reciprocating aircraft engine fuels of different grades, and jet aircraft fuels, grades JP-1, JP-3, JP-4, and JP-5.

Burning oils include kerosene, used for lanterns and heating appliances, and illuminating oil for long-time burning signal lamps.

Fuel oils include diesel fuels of several grades, one of which is for submarines; burner fuel oil for vaporizing pot-type burners, for domestic heating, for low-speed diesel engines and for burner installations; and boiler fuel oil of two types: Navy Special, which is used for powering most Navy vessels, and Navy Heavy, which is used for old type ships and at shore installations.

LIQUID FUEL HANDLING EQUIPMENT

Various types of equipment are used in the handling and storage of fuels, and equipment may vary from one activity to another. Some of the common types of equipment and accessories which you may encounter in your work are discussed in following sections.

PUMPS

Pumps used in the handling of fuel must be capable of dependable service over the full range of operating conditions anticipated at any activity. Such conditions include variations in specific gravity, temperature, viscosity, and fuel volatility, and may also include varying conditions of suction and discharge.

Types of pumps that you may find commonly used at overseas base tank farms include the 6-in., two-stage and the 350-gpm centrifugal pumps and the 300-gpm rotary pumps.

The 6-inch, two-stage centrifugal pump has a split-type case. The impellers may be operated in parallel or in series by use of the external cross-over provided with the pump. Calculations for such pumps involving fuel at 60° F may be based on the following listed capacities and pressures (head):

Impellers	Fuel	Barrels Per Hour	Ft. Head
Parallel	Gasoline	2000	275
Parallel	Navy Special fuel oil	1500	200
Parallel	Diesel oil	1800	250
Series	Gasoline	715	555
Series	Navy Special fuel oil	530	400
Series	Diesel oil	640	500

The single-stage 350-gpm centrifugal pump is used for Navy Special fuel oil, diesel oil, and gasoline service and may be used for pumping water. (See fig. 13-1.) Such a pump has a tdh (total discharge head) of 290 feet and is equipped with 6-inch and 4-inch flanged suction and discharge connections, respectively. Calculations for such pumps involving fuel oils at 60° F may be based on the following listed capacities and pressures (head):

Fuel	GPM	Ft Head
Gasoline	350	290
Navy Special fuel oil	265	210
Diesel oil	315	260

The 300-gpm rotary pump is used for Navy Special fuel oil or diesel oil. (See fig. 13-2.)

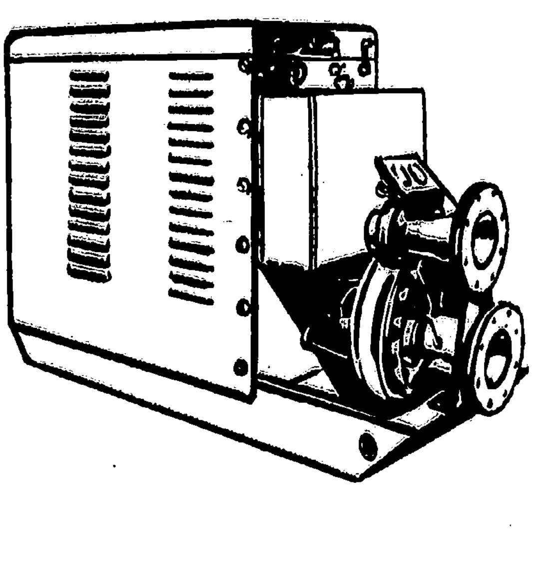

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Figure 13-1. — 350-gpm centrifugal pump.

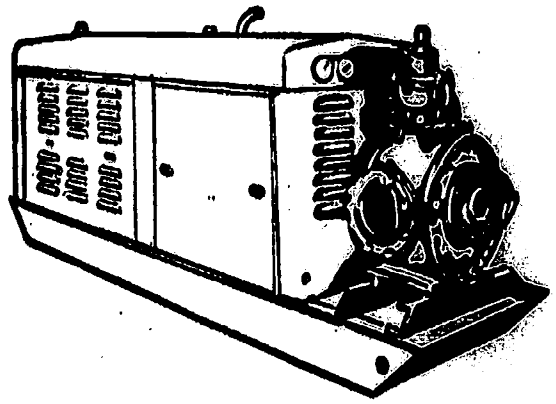

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Figure 13-2. — 300-gpm rotary pump, fuel oil, fixed-base.

Such pumps are designed with a capacity of 300-gpm at 370 ft total delivery head (tdh), which is approximately 160 psi. The engine and pump drive assembly for 300-gpm rotary pumps are enclosed in a sheet metal housing that has removable side panels; the entire unit is skid-mounted.

HEATERS

Heaters are necessary to ensure satisfactory flow of fuel oil from the storage tank to the point of delivery. Heaters use saturated steam as the heating medium. Two types of heaters used are convection type and in-line type heaters.

Convection type heaters are installed inside a storage tank. This type must be capable of passing through a 24-inch manhole. Convection type, intake heaters should each have a capacity which will heat a full tank of Navy Special oil from 55° to 65° F in 24 hours.

In-line heaters are of shell and tube construction and are of two general types: (a) one with one open end for installation on the outlet fuel line inside a tank, such as a bayonet-type heater, and (b) one with both ends closed for installation in the pipeline outside a tank.

In-line heaters must be capable of heating fuel oil passing through them from the ambient tank temperature of 120° F. In-line heaters installed in tanks should be designed to allow removal of heater tube bundles without emptying a tank. In multipass in-line heaters, the oil temperature rise must not exceed 30° F per pass.

For subsurface tanks, heaters may be mounted through the same openings used for vertical pump mounting.

The following accessories should be provided for in-line heaters:

1. Thermometers in fuel inlets and outlets and steam inlets.
2. Pressure gages in fuel inlets and outlets.
3. Automatic controls to regulate outlet fuel temperatures.

PIPING

All of the onshore piping and fittings, 4 inches and larger in size, used in the overseas base fuel storage tank farms are of the grooved type, for use in making connections with bolted clamp-grooved couplings. Light-weight spiral-welded pipe is supplied in 4-inch, 6-inch, 8-inch, and 12-inch sizes in 20-ft lengths, with a grooved nipple welded on both ends of the pipe. When shorter lengths are required, sections may be rewelded.

The limited quantity of small pipe and fittings required in construction of tank farms is of the screwed type. Sea loading lines are assembled from 6-inch, 8-inch, and 12-inch, standard weight beveled-end steel pipe and the joints are welded.

For protection, pipelines are usually laid from 18 inches to 38 inches underground. Unless there is a more or less continuous downward slope, oil will not flow through pipelines unaided. Therefore, pumping (booster) stations must be installed at intervals. (See fig. 13-3.) A pumping or booster station consists of suitable storage tanks, motive power, and pumps for pumping the oil along the line.

In planning the course of pipelines in combat areas, advantage is taken of all possible natural growth. All natural depressions in the earth, such as roadside ditches, are utilized. If pipeline trenches are not filled in, dirt is banked along both sides of the pipe to eliminate pipe shadow, or the entire line is camouflaged by painting. Tanks and pumps used in connection with pipelines are frequently set in recessed pits, installed under natural cover, or disguised by the use of garnished nets.

VALVES

Gate valves are used for fuel oil and diesel oil services. The nonrising type of gate valve is normally used, but the rising stem, outside screw, and yoke types of gate valves are used in manifolds and at other locations where a positive visual indication of a valve's position is essential.

Plug or ball valves are used for jet fuels and gasoline services. At locations such as tank inlets, pumping stations, and piers, they must be gear-operated to prevent the possibility of too quick closure, causing surge pressure shock in the piping.

Nonslamming-type check valves should be installed at each pump discharge.

GASOLINE-WATER SEPARATOR

The water-gasoline separator is a 300-gpm self-contained unit designed to remove water from gasoline. (See fig. 13-4.) It consists of a steel shell that has a removable head, a 4-inch iron pipe size (ips) flanged inlet and outlet, and a water accumulation pump. Units of this type are mounted on steel legs; they are provided with strainers, drainage gage valve, interconnection tubing, and so on.

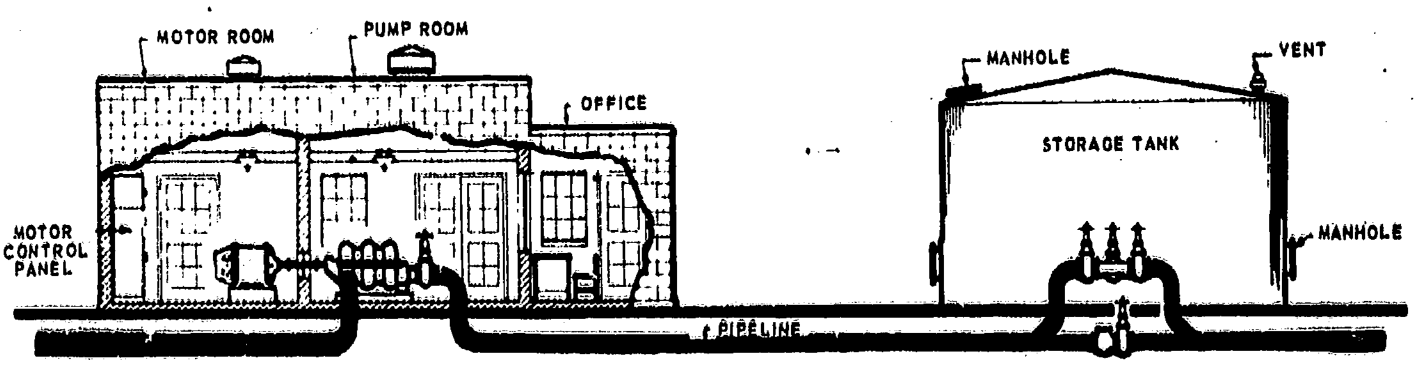

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Figure 13-3. — Pipeline pumping station.

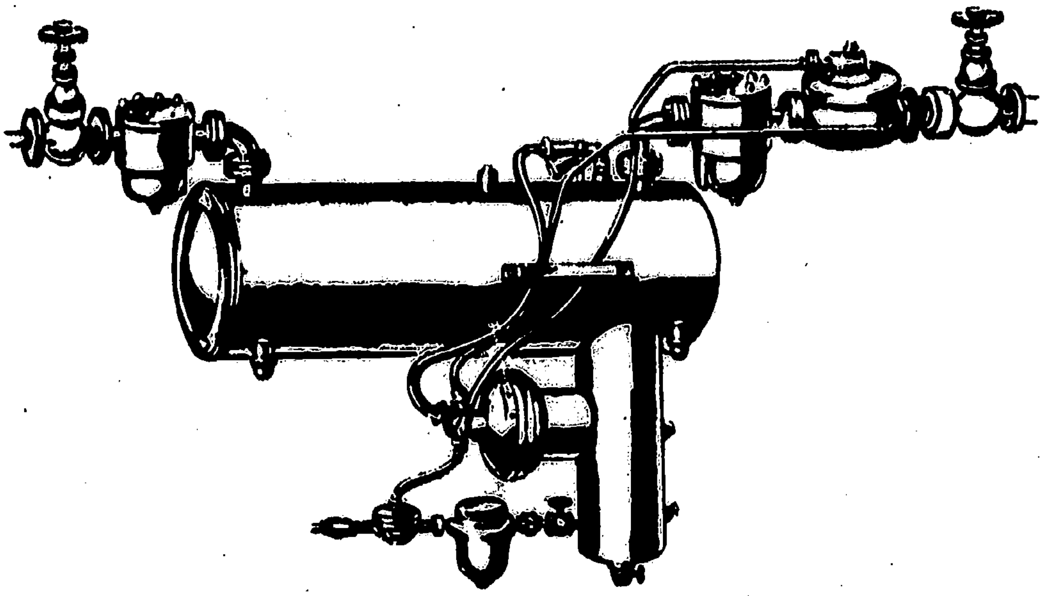

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Figure 13-4.—Separator, water-gasoline.

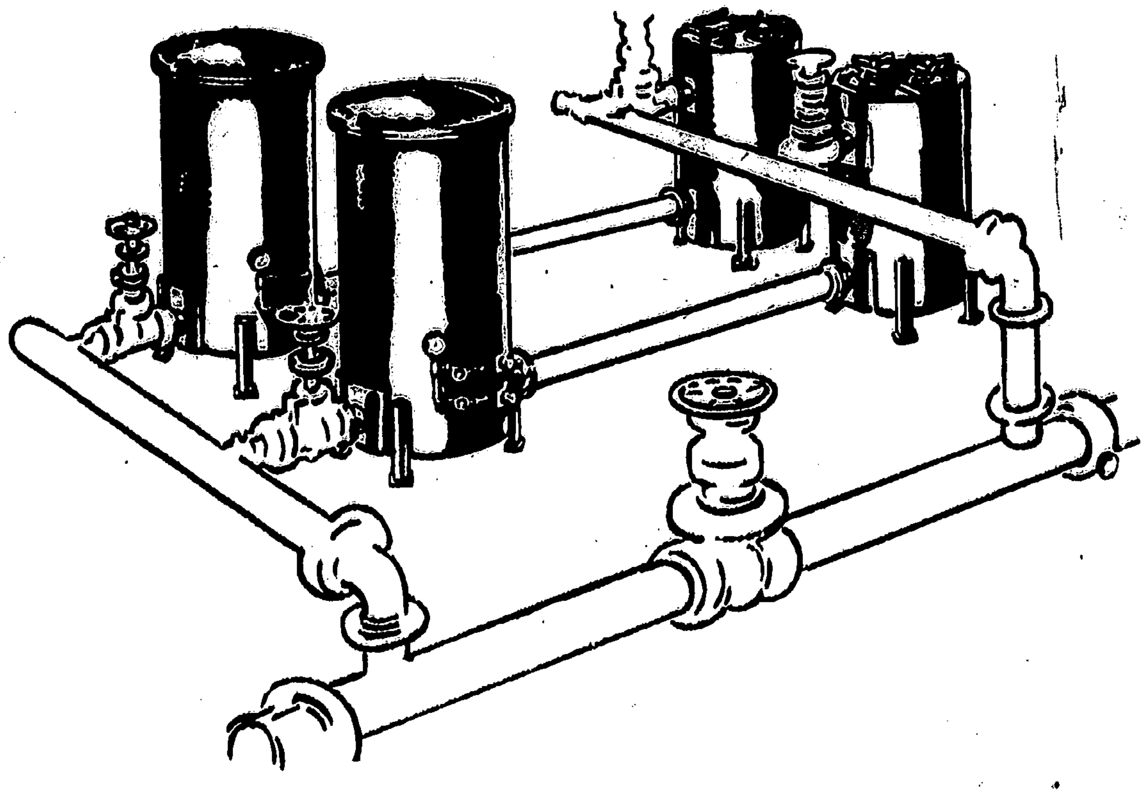

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Figure 13-5.—Clarifier and strainer, diesel oil.

GASOLINE-WATER SEPARATOR/FILTER FOR AVIATION FUELS

The separator with filter for aviation fuels is a self-contained unit designed to remove water and microscopic particles from 600 gallons of fuel per minute at a maximum working pressure of 150 psi. The shell has a removable head, a 6-in. ips flanged inlet and outlet, and a water accumulation sump. This unit is furnished with a remote control valve, a liquid level gage, air eliminator strainers, interconnecting tubing, and so on.

DIESEL OIL STRAINER AND CLARIFIER

The diesel oil strainer is used to remove dirt, scale, and other foreign material from oil. The strainer has a capacity of 2,400 gallons or 57 barrels per hour of No. 3 diesel oil at 100 psi working pressure. The strainer contains four removable elements with scraper-type cleaning knives. The inlet and outlet of the strainer are 4-in. flanged connections; the strainer is equipped with air vents and pressure gages. The diesel oil strainer and clarifier are illustrated in figure 13-5.

The diesel oil clarifier is used to remove acids, resins, gums, and other impurities from oil. The clarifier has a capacity of 9600 gallons per hour (approximately 229 barrels) of No. 3 diesel oil at 100 psi working pressure. Such a clarifier contains replaceable, fuller's-earth and rolled-cellulose, adsorbent and absorbent filter elements. The clarifier has 4-in. flanged inlet and outlet connection openings.

TANK TRUCKS

In transporting petroleum products in advanced areas, the motor vehicle provides a very adequate solution to the transportation problem presented when neither pipelines nor railroads are available, or where tactical conditions do not warrant the use of these means.

There are various types and sizes of tank trucks and trailers used to transport petroleum products. One type is shown in figure 13-6. Commercially, 6,000- to 8,500-gallon tank trucks are used extensively, although larger units are in use in some parts of the country. At military stations, 750-gallon tank trucks and 3,500-gallon semitrailers are commonly used as refuelers.

CONTROLS

A number of automatic controls are used in fuel handling operations. A few general types that may concern you in your work are discussed briefly below.

Temperature controls should be provided at all fuel heaters to control the outlet temperatures of the fuel. Each control consists of a sensing element in an outlet fuel line activating a thermostatic valve in the steam supply line to the heater. These controls are self-actuating and need no external power source. Each control will have a manual set point which is variable over a suitable range. A bypass is provided around all control valves with a throttle valve for manual operation.

A flow control valve is needed at the outlet of each meter, clarifier, and filter-separator to prevent excessive flow through the equipment. The maximum flow setting should be 110 percent of rated flow. Control valves of the self-actuating type, controlled by differential pressures across a flow orifice, are used. Set points must be manually adjustable over a suitable range.

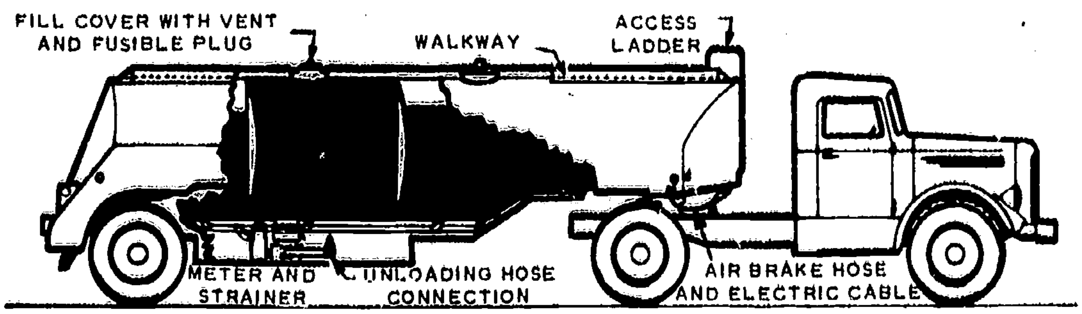

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Figure 13-6. — Tank truck.

Parallel transfer pumps supplying an issuing facility with varying demand flow rates are sequenced automatically by flow-sensing-sequence equipment. Lead pumps may be started by either of two methods. One method is by means of pushbutton at an issuing facility. The other method is automatic starting by a pressure switch when the system pressure falls on opening a valve at the issuing facility. This latter method requires the system to be pressurized at all times.

Automatically controlled pumps with emergency stop buttons having lock-key reset are provided at issuing stations and at the central supervisory control station.

Transfer pumps will shut off automatically on suction failure or sudden drop in discharge pressure signifying a line break.

Adequate means are provided to keep the pump from overheating due to operating with a blocked discharge. This is prevented by a lock-stop button which is used at each remotely operated pump for maintenance operation. An indicator light should also be provided at the control station to indicate when a pump is operating. When a pump is controlled automatically, have a signal light and/or alarm to indicate pump failure.

Where necessary, remote-operated valves should be provided on storage tank inlet and outlet lines, suction and discharge of transfer pumps, and transfer lines at fuel piers and other remote locations. Remote-operated valves may be either motor-operated or the solenoid pilot type hydraulically operated by piston or diaphragm. These valves should have green and red (open and closed) indicating lights at pushbutton control stations.

Level control valves should be provided on day storage tanks (which supply high-speed fueling facilities for aircraft) to prevent over filling tanks.

Where practicable, equip tank level gages with high and low level contacts, which should function as follows:

1. High level switch closes inlet valve, or stops transfer pump and sounds alarms.
2. Low level switch stops dispensing pump and sounds alarms.

ACCESSORIES

Accessories commonly used for fuel handling purposes include meters, pressure gages, thermometers, and strainers.

Fuel meters are required for issuing facilities, diesel fuel oil clarification plants, and other such installations as specified by the Naval Facilities Engineering Command (formerly named the Bureau of Yards and Docks). Fuel meters of 700 gpm capacity and smaller will either be rotary, oscillating, or reciprocating piston displacement type. Meters larger than 700 gpm capacity may be the flow sensing type.

Meters should be constructed of noncorrosive materials so that accuracy will be maintained even when metering fuel containing small amounts of entrained fresh or salt water.

Positive displacement meters should be protected from damage or derangement by use of strainers and flow limiting valves.

Pressure gages are installed on the discharge side of each fuel pump, the inlet and outlet of each fuel oil heater, and on fuel pipelines at each loading or receiving point. These gages must be of the range and dial size as necessary, but not less than 0 to 160 psi pressure range and 4 1/2 in. diameter. This will be within the normal pressure range and will allow good visibility of the gage.

Pressure gages should be used upstream and downstream of strainers, clarifiers, and filter-separators. Compound gages are installed on the suction side of each pump at fuel storage tanks. Block and bleed valves are provided in each pressure gage connection. This allows removal of the gages when necessary and to purge air.

Thermometers are provided in fuel and diesel oil distribution piping systems at each loading and receiving point and on the inlet and outlet of each heater.

Wire mesh strainers are provided in all fuel receiving lines between a reception point and a storage tank. Strainers also are needed on suction lines to pumps, inlet sides of fuel meters, temperature cntrol valves, flow-control valves, and upstream of filter-separators and clarifiers. These are used to remove particles that tend to clog or damage this equipment. Strainers are of steel construction and fitted with removable baskets of fine Monel metal or stainless steel mesh with large mesh reinforcements.

TANK FARMS

A tank farm is composed of a group of bulk storage tanks and related facilities such as docks, loading racks, pumping units, pipelines, an auxiliary power unit, and a fire protection system. Other terms such as bulk storage installation, storage terminal and military fuel depot are sometimes used to designate this type of military activity. Tank farms vary in size—the size and number of storage tanks depending upon the volume and type of petroleum products to be handled. Some tank farms are attached to or are part of an operating base. Others are isolated from other military activities.

Some tank farms have underground steel or concrete tanks, while others have conventional above-ground tanks. A small terminal usually has tank facilities to handle 250,000 gallons of petroleum products per month. A large tank farm may handle many millions of gallons in the same period and will, therefore, have a large number of tanks.

Note that detailed information on tank farms is not provided in this training manual. Special schools are available to train men in tank farm operations. Some of the SEABEES who are assigned to tank farms, however, do not always have an opportunity to attend one of these schools. Therefore, some of the basic information you should know regarding tank farms is presented here and in the following chapter. This information will be especially useful to personnel assigned to tank farms who have had no special training or prior experience in this line of work.

TRANSFER SYSTEMS

Each tank is provided with a system for transferring fuel from the tank to dispensing facilities. There are two types of systems used by the Armed Forces: the mechanical system and the hydraulic system.

Mechanical pumping systems may be either above or below ground. The mechanical system utilizes a motor-driven pump or pumps to transfer fuel from the tank. A typical underground mechanical system is shown in figure 13-7. Pumps normally have a capacity ranging from 150 to 300 gpm and are generally driven by electric motors. The pumps may be located at grade or in pits and are operated by switches located at dispensing points. Switches are provided also for entire system shut-down in case of an emergency.

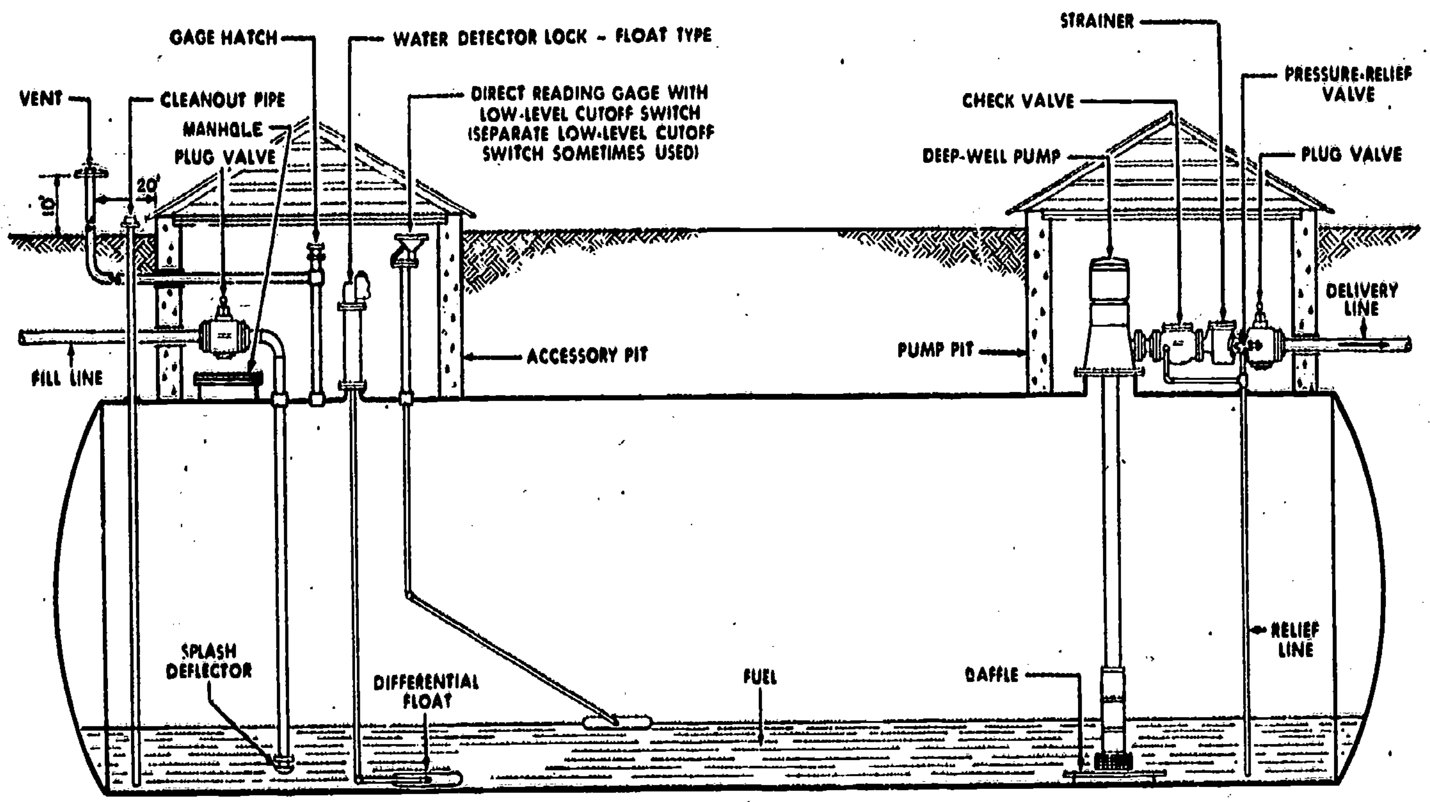

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Figure 13-7. — Typical underground mechanical pumping system.

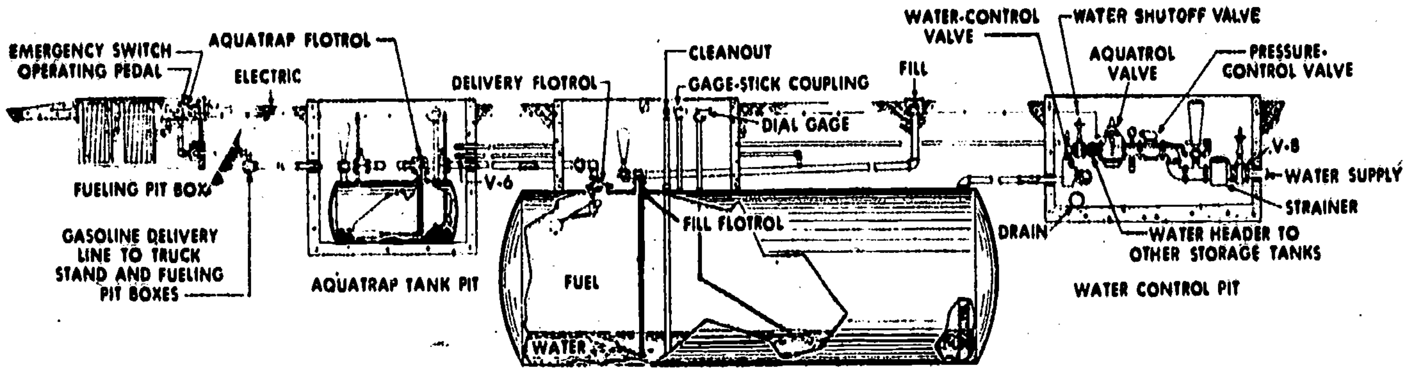

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Figure 13-8. — Typical hydraulic system for transferring fuel from storage tanks.

The hydraulic system is used extensively at air stations. This system uses water pressure as the force to deliver fuel from underground storage tanks to truck-fill stands or fueling pits. Only fuels which are lighter than water and do not mix with it can be stored in hydraulic systems. The storage tanks are always full of water and fuel in varying proportions, the fuel floats on top.

A diagram of a typical hydraulic system is shown in figure 13-8. The gasoline line is connected to the top of a tank and the water connection extends to within about 6 inches of the tank bottom. The operator controls the flow of water to the tank by a series of valves. These include a remotely controlled three-port, two-way valve shown in figure 13-8 as the aquatrol valve, and a manually operated, three-port, two-way valve identified in figure 13-8 as the water control valve.

When in the fueling position, the valves allow water, under regulated pressure from the base water supply system, to enter the tank through the water connection, thus forcing gasoline out of the tank through the delivery line to the dispensing outlets. The desired operating head or pressure of water is maintained automatically by the pressure control valve. The operator determines when the fuel supply is running low by means of a measuring stick or by observing the direct-reading tank gage.

When in the nonfueling position, the water control valve permits water (forced out of the tank by the filling operation or by expansion of the tank contents due to change in temperature) to be spilled from the drain port of the valve into the water control pit drain.

RECEIVING AND ISSUING FACILITIES

Fuel pipelines are provided for receiving the product in bulk from a connection made to a commercial pipeline, from a ship or barge moored at an unloading dock, or from an unloading header at a tank car loading rack. If necessary, a booster pump is provided along this fuel line between the receiving point and the storage center, for the purpose of boosting pressure in the line. Pipeline flow may be reversed in operation to effect issue of product.

In any type of receiving or issuing facility, provisions are made for electrically grounding ships, barges, or tank cars before and during the transfer of petroleum products. Grounding for tank car loading racks includes the bonding of railroad sidings and the insulating of trackage to prevent any stray currents from entering the plant or to prevent the formation of static electricity. If transfer takes place from commercial pipelines, the line is separated from the storage center piping by an insulated joint. This prevents a line provided with cathodic protection from draining current from plant lines and tanks. The joint also prevents stray currents in the pipeline from entering the plant.

If unloading is to be done at a regular tank car loading rack, facilities are provided for unloading cars from bottom outlets. Tank cars are loaded overhead through submerged-type loading arms from swing-type connections and risers on the tank car loading rack. Trucks are loaded from truck loading racks or from separate truck loading stems located along roadways and at a safe distance from normal traffic patterns.

On docks, hose supports are provided to prevent wear and tear in the unloading hose and to permit easy handling of the hose. Pans are also provided under all unloading connections to catch any drip or slight spill.

AUXILIARY FACILITIES

Auxiliary facilities at tank farms differ widely, although most tank farms have a full complement of equipment such as communication facilities, fire fighting equipment, cargo hose, water transportation, strainers, diesel fuel filters, and equipment for confining and recovering oil spilled on the water. Many tank farms also have facilities for receiving ballast from tankers or ships.

Most tank farms are furnished with at least a minimum of testing equipment while others are equipped with complete laboratory facilities for testing petroleum products. Some tank farms also have contaminated oil recovery systems.

Utilities such as water supply, salt or fresh water for fire protection, sewage disposal, and power supply will vary in tank farms. Frequently, electric power is supplied by public utilities. This power is often supplemented by a source of power at the military activity. Sewers discharging oily water are kept separate from sanitary sewers because oily waste and sewage readily combine to form an emulsion of refractory quality. The installation of gravity water/fuel separators at outfalls of drainage ditches is necessary to eliminate oil contamination of navigable waters, in the event of oil spills or tank overflows.

TANK ENCLOSURES

Tanks installed above ground must be surrounded by a dike. With underground tanks, careful consideration should be given to construction of earth dikes. The purpose of earth dikes is to impound escaping oil where rupture of an underground tank in a hillside location would endanger other activities and structures at elevations lower than the tank.

The volume enclosed by the dike, when flooded to within 1 ft of the top, must be at least equal to the tank capacity. In some cases, the nature of a terrain may necessitate enclosing two or more tanks within the same dike. But this should be avoided, if possible.

Concrete steps with pipe handrails should be provided on one side of passage across a dike. The steps should be located at the most accessible points, preferably on the same side as the access stairs to the tank roof.

Reinforced concrete dikes should be used in confined areas, or where materials impervious to fuel products are not economically available. Steel ladders with handrails must be provided on top for passage over dikes.

For good drainage the area within a dike should be sloped to a low point where a sump is located. Connect the sump with a drain pipe to the outside of the dike for gravity discharge to the surrounding area, which must be adequately drained, or connect it to a storm sewer system. This drainage line may be controlled by a manually operated valve.

TANK FARM PROTECTION

At tank farms, fire water systems and foam systems are needed for protection against fire.

Water is necessary for fighting brush and grass fires, cooling exposed and burning tanks, and supplying any foam firefighting system. It is important that hydrants be so placed that essential water rates can be supplied through hose runs not exceeding 300 ft. In any case, a hydrant should be located within 100 ft of any foam lateral.

In regards to foam systems, fixed installations may be used in relatively small tank farms. Semiportable installations are generally more desirable where tanks are equipped with foam applicators. Foam application means may incorporate aspirating nozzles, or foam may be generated at central foam houses, or by mobile equipment. Portable installations, consisting of foam towers or nozzles fed by hose from mobile equipment, are considered auxiliary protection.

Fire alarm boxes should be placed in accessible locations not more than 500 ft from any possible fire hazard. Signaling systems must conform to those established by local authorities.

STORAGE OF PACKAGED PRODUCTS

Although the largest percentage of military petroleum products is stored in bulk and dispensed by bulk handling equipment, military operations may require the handling of these products in relatively small containers. Such containers are often referred to as PACKAGES. The 55-gallon drum and the 55-gallon can are two common types of packages used for storage of petroleum products.

For many years, the 55-gallon drum has been used for storing and transporting packaged gasoline and fuel oils. Drums used by the military forces are 16-gage or 18-gage containers having bungs in the end for filling and emptying. When filled, each weighs approximately 400 pounds.

The 5-gallon can is used extensively by the military forces to supply gasoline to ground units in the field. These cans are made of 20-gage steel and, when filled, each weighs approximately 40 pounds. This container (officially designated Can, Gasoline, Military 5-gallon) is commonly known as an AMERI-CAN or BLITZ CAN. It has a large 2-inch screw-type closure, from which gasoline may be poured by the use of a flexible nozzle. It does not require an adapter.

Many other petroleum products, such as lubricating oils, gear lubricants, and lubricating greases, are handled in cans, drums, pails, and other packages, ranging from 2 ounces to 500 pounds, depending on the requirements and intended use of the products.

All containers used for storing petroleum are required to be clearly marked with the contents and date of packaging.

In the case of drummed products, the type of product and the facilities available will determine whether inside or outside storage is appropriate. Whenever possible, lube oils and greases are stored indoors. Fuels, including used fuel containers, should be stored out of doors away from buildings. Empty fuel containers which are new or have been reconditioned since last containing fuel should be stored indoors whenever possible.

When drums are to be stored outdoors, a level site should be selected that is not in or adjacent to a congested area. Too, the contour of terrain should be such that an immediate runoff of surface water is possible through a system of open ditches. Drainage into any sewer system is prohibited. An adequate supply of water for firefighting purposes should be taken into consideration in the selection of this site. The drum storage area should be located or arranged so that escaping flammable vapors normally flow away from operational areas and sources of ignition. Gasoline vapors are heavier than air and tend to lie in a stratum less than 4 feet above grade and flow toward lower ground much as liquid flows to a lower level. The drums should be stored horizontally on suitable dunnage, in double rows, butt to butt with liquid pressure on the closures. Normally, low flash products should not be stored in rows more than 35 drums long nor more than 3 tiers high. For the storage of high flash products the quantity of drams stored in a tier may be doubled.

When covered storage is required, clearances of at least 100 feet should be maintained between warehouses or from other buildings, spark producing equipment, and fires of any kind. Warehouses should be constructed of fire resistant materials and only the ground floor used for storage of packaged products. Adequate firefighting equipment should be available. Storage areas in each warehouse should be planned so that products can be segregated into sections with adequate aisles and curbing placed around each section to prevent the spread of spilled liquids to other sections of the warehouse. The primary objective in the arrangement of containers is to store the maximum quantities of products in a limited space while maintaining fire protection and providing ease and safety in handling the containers.

Filled 5-gallon gasoline containers are normally stored in outdoor storage areas. To conserve space and to provide stability of stacks, filled 5-gallon gasoline cans should be stacked in pyramids, normally 4 tiers high, unless cans are palletized.

All packaged lubricants and greases in packages other than 55-gallon drums should be under covered storage. If covered storage is not available, lubricating oils and greases may be stored outdoors provided the containers are protected from water, heat, and sun by fire retardant tarpaulins. Storage should be such as to provide for segregation of the products into sections. The lubricants should be stacked on pallets or adequate dunnage.

Empty containers should be protected from damage by careless handling, and from contamination of the interior by dirt, water, and other extraneous matter. Tightly closed containers will retard interior corrosion to a great degree. New or reconditioned containers received for storage will have no product markings thereon. These containers should be inspected periodically to ensure their usability at all times. Containers evidencing interior or exterior corrosion should be removed for possible reclamation. Empty containers previously containing products should be treated as explosion hazards and handled accordingly prior to reconditioning. Closures should be tightly closed, as an open bung or vent emits hazardous vapors for some time after removal of the product. Economically repairable containers may be reconditioned. Empty drums and cans may be stacked by any of the methods prescribed for filled drums and cans but without height limitations.

MEASUREMENT OF QUANTITY

Remote tank gage and temperature reading and recording devices have been developed in recent years which have demonstrated a high degree of accuracy. Some types of this equipment have been installed at several Navy fuel facilities.

The most common types of remote gage reading devices make use of float equipment for determining the tank liquid level height. Liquid level measurements and temperature data can be transmitted electronically to a central control point, on demand, where they may be directly observed or recorded for later use. Primary use of this equipment is for quickly determining: (1) present stock position; (2) that large transfers are proceeding according to plan; and (3) the existence of leaks in tanks. However, these devices are not yet used by the Navy in determining quantities for accounting purposes.

In this phase of our discussion, we are concerned with standardized methods employed to manually measure the quantity of a product in a given tank, the amount of water in the tank, and the temperature of the product. Another important topic, sampling, is discussed later in this chapter.

GAGING

For our purposes here, gaging is the mechanical measurement in feet, inches, and fractions of an inch of the quantity of a product in a storage tank or tank truck. Gaging is performed with a wooden stick or a steel tape marked in feet, inches, and eighths of an inch. In the latter case, the tape is wound on a hand reel that comes equipped with a brass plumb bob or suitable weight to hold the tape taut. (See fig. 13-9.) The tape is fastened to the bob with a snap, and the tape markings include the length of the bob.

There are two basic types of procedures for obtaining gagings, and the results are known as ullage gaging and innage gaging.

An ULLAGE (or OUTAGE) GAGING is the distance from a given point to the top of the container down to the surface of the liquid. This measurement is usually taken on ships' tanks. In taking ullage, the tape is gradually lowered and swung back and forth until the tip of the bob breaks the surface and causes a ripple. At this point the tape is held steady and a reading taken at a reference point at the gage hatch. The steps in measuring ullage are shown in figure 13-10.

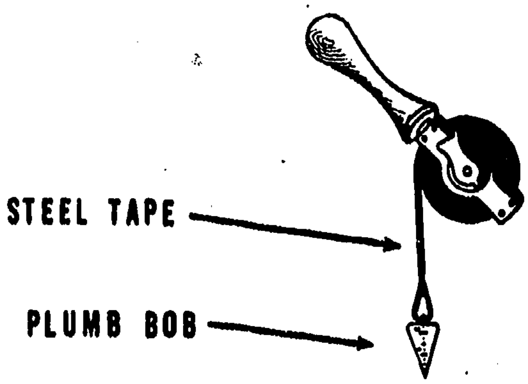

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Figure 13-9.— Tank gaging tape and plumb bob.

An innage gaging is the depth of liquid in a tank, measured from the surface of the liquid to the tank bottom. (See fig. 13-11.) This measure is commonly taken on vertical shore tanks above and below ground.

The frequency of taking tank gagings varies with the activity of the depot. All gagings are to be taken manually unless otherwise directed by the fuel officer. The following suggestions are practical minimums:

1. Inactive tanks should be gaged at least once a week.
2. Tanks first filled or filled after having been empty for some time should be gaged once a day until it appears that there is no leakage.
3. In case the gaging record of any tank appears irregular, all other tanks into or out of which leakage might have occurred should be gaged for a check.
4. Every tank that is apt to be worked or issued from during the day should be gaged at the start of the day.
5. Tanks involved, or that may be used, must be gaged before starting any receipt by the depot. Such gagings will be witnessed by a representative of the ship (or pipeline carrier), and must be verified by two men at the depot.
6. Tanks must be gaged after the completion of any receipt. The final official gaging should be deferred for 12 hours, if practicable, to ensure against errors caused by foam or air. A preliminary check gaging should be taken 30 minutes after receipt. Then, if it is not practicable to wait for 12 hours, the official gage may be taken after two gagings at 30-minutes successive intervals agree.

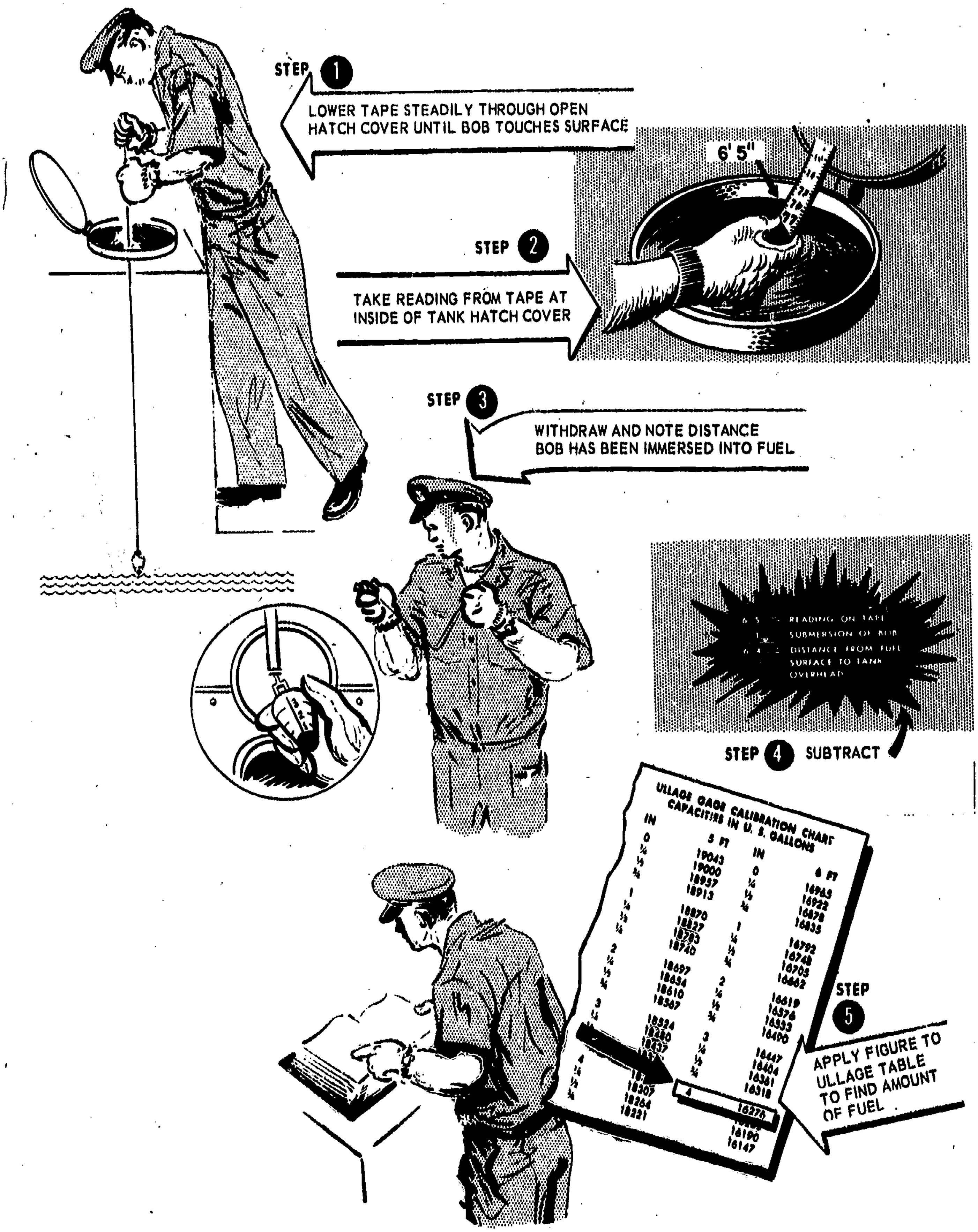

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Figure 13-10. — Steps in measuring ullage.

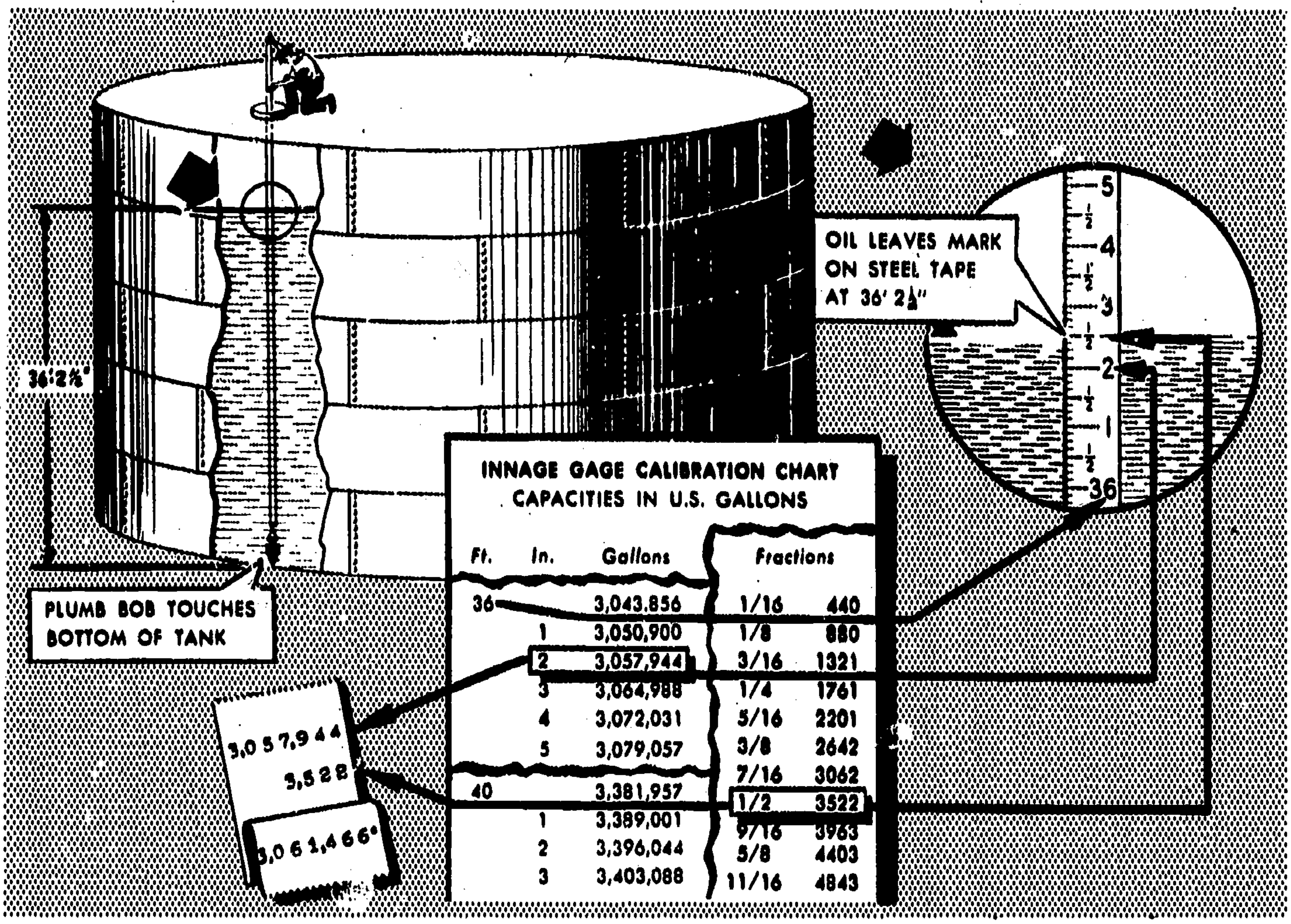

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Figure 13-11. — Measuring innage.

7. Tanks invoved must be gaged before and after any issue or transfer. Such gagings should be verified by a second man. The agency receiving the issue may verify the gaging or it may be verified by an inspector acting for the receiver of the issue. In many cases this outside verification will not be practicable. There should be no real necessity for it in case of intra-Navy issues.

8. Should any depot load tank ships for offshore deliv ry, gagings will be witnessed by an inspector.

MEASUREMENT OF WATER

In many cases, there is a layer of free water in the tank bottom. The depth of this bottom water is obtained by taking a WATER CUT. This is usually accomplished by coating the plumb bob or gaging tape with water-finding paste.

To obtain the water cut in a fuel oil tank, the bob must be allowed to rest on the bottom of the tank, as illustrated in figure 13-11, from 30 to 60 seconds. For heavy fuel oils, it may be necessary to cover the water-finding paste with lubricating oil. After the bob is withdrawn, the fuel oil is washed off gently with diesel oil in order to reveal the water mark, shown by the change in color of the water-finding paste. For diesel fuel oil or gasoline the water cut is obtained more quickly. In this case the water-finding paste need not be covered with lubricating oil. The water cut in a tank is subtracted from the total quantity of the product as shown by the innage or ullage gaging to determine the actual amount of petroleum product in a tank. The amount of water should be calculated at the same time and then reported. The steps for taking a water cut are shown in figure 13-12.

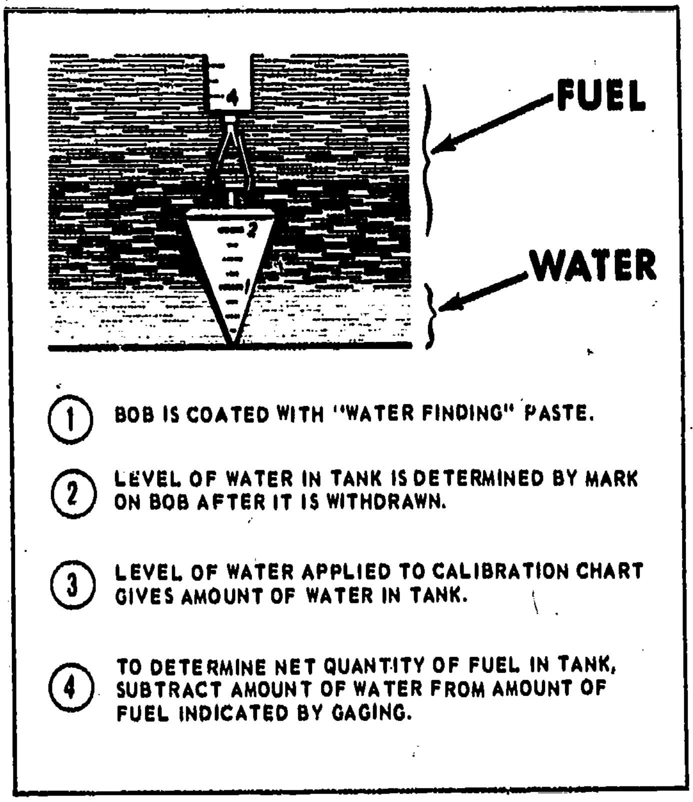

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Figure 13-12.—Steps in taking a water cut.

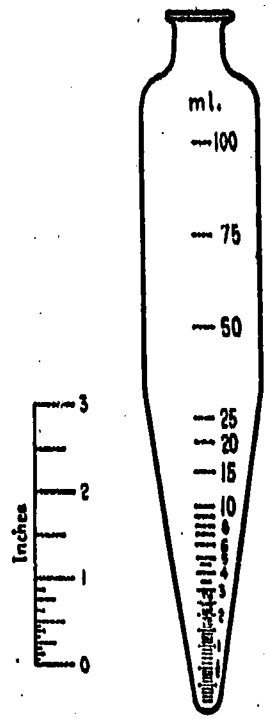

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Figure 13-13.—ASTM cone-shaped centrifuge tube.

SEDIMENT AND WATER (CENTRIFUGE METHOD)

The centrifuge method is an excellent method for determining the amount of water and insoluble solid impurities petroleum products. The apparatus used in this method is the ASTM cone-shaped centrifuge tube, shown in figure 13-13. In the centrifuge method, the oil to be tested is diluted with benzene and centrifuged under specified conditions. When this process is completed, the combined volume of water and sediment, the combined volume of water and sediment in the bottom of the tubes is read on each tube and recorded as the percentage of water and sediment, centrifuge method. This method for sediment and water is frequently referred to as BS & W (bottom sediment and water).

MEASUREMENT OF TEMPERATURE

The AVERAGE temperature of a product is required to calculate its volume at a standard temperature of 60° F. It is important to determine temperatures accurately because an error in determining the average temperature of a product causes errors of considerable magnitude in calculating the volume of a product at 60° F.

To arrive at an accurate average, temperatures of liquid petroleum products are determined at specified locations in tanks, ships, barges, and tank trucks. Temperature readings are then averaged arithmetically to obtain the average temperature.

The thermometer most commonly used for taking tank temperatures is a standard cup type of 0° to 180° F range, marked to 1° F divisions, with an open metal cup of about 100-cc capacity surrounding the bulb. For heavy fuel oil, or when accurate results are wanted more quickly in a tank that is not at approximately the same temperature throughout, a special trap thermometer is used. This thermometer is suspended at least a foot from the shell. For heavy fuel oils the thermometer may be suspended in the tank at all times. In tanks of over 5,000-barrel capacity, several openings are usually provided through which temperatures are taken.

Considerable time is required for a thermometer to reach equilibrium in fuel oil. The length of time varies greatly with conditions; it seldom will be under 5 minutes, and may be as

Table 7

0-100° API **50-100° F.**			**Volume Reduction to 60° F.** **(Abridged Table)**				**ASTM—IP**

Observed Temperature, °F.	**Group Number and API Gravity Range at 60° F.**							
	Group 0	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**
	0-14.9° API	**15.0-34.9° API**	**35.0-50.9° API**	**51.0-63.9° API**	**64.0-78.9° API**	**79°0-88.9° API**	**89.0-93.9° API**	**94.0-100.0° API**
	Factor for Reducing Volume to 60° F.							
50	1.0035	1.0040	1.0050	1.0061	1.0070	1.0080	1.0084	1.0090
51	1.0031	1.0036	1.0045	1.0054	1.0063	1.0072	1.0076	1.0081
52	1.0028	1.0032	1.0040	1.0048	1.0056	1.0064	1.0067	1.0072
53	1.0024	1.0028	1.0035	1.0042	1.0049	1.0056	1.0059	1.0063
54	1.0021	1.0024	1.0030	1.0036	1.0042	1.0048	1.0051	1.0054
55	1.0017	1.0020	1.0025	1.0030	1.0035	1.0040	1.0042	1.0045
56	1.0014	1.0016	1.0020	1.0024	1.0028	1.0032	1.0034	1.0036
57	1.0010	1.0012	1.0015	1.0018	1.0021	1.0024	1.0025	1.0027
58	1.0007	[illegible]	[illegible]	1.0012	1.0014	[illegible]	[illegible]	1.0018
				[illegible]	[illegible]			[illegible]

132.55

Figure 13-14. — Portion of Table 7, ASTM-D1250 Petroleum Measurement Tables.

much as 20 minutes. In a diesel fuel oil or gasoline tank, less time is required.

VOLUME CORRECTION

The unit of measurement for determining quantities of bulk petroleum products both within and without the continental U.S. is the barrel of 42 U.S. gallons at a temperature of 60° F. All corrections on fuel oils, diesel fuel oils, gasolines and other light fuels are made in accordance with ASTM-IP Petroleum Measurement Tables. Table No. 7, a portion of which is shown in figure 13-14, gives the factors for converting oil volumes observed at temperatures other than 60° F to the corresponding volumes at 60° F for ranges of values of API gravity at 60° F. This table is an abridged form of table 6a and is intended for use where accuracy less than that given by table 6a can be tolerated.

Thus the volume correction of a product, having the characteristics which would place it in Group No. 2, would be determined as shown in figure 13-15.

140,000 x 1.0030 = 140,420

Quantity received in U.S. gallons at 54°F ____

Volume correction factor for observed temperature at 54°F, taken from Table 7, ASTM-D1250 Petroleum Measurement Tables, Group 2 (API Gravity 36.1 at 60°F.) ____

U.S. Gallons at 60°F ____

10.31.0

Figure 13-15. — Example of volume correction to 60° F.

$140{,}420 \div 42 = 3{,}343\frac{1}{3}$

U.S. Gallons at 60°F ____

U.S. Gallons per barrel ____

Barrels at 60°F ____

10.31.0

Figure 13-16. — Example showing computation from gallons to barrels.

ASTM—IP

Table 8
Pounds per U. S. Gallon and U. S. Gallons per Pound

30-45° API

API Gravity 60° F.	Pounds per U. S. Gallon at 60° F.	U. S. Gallons at 60° F. per Pound	API Gravity 60° F.	Pounds per U. S. Gallon at 60° F.	U. S. Gallons at 60° F. per Pound	API Gravity 60° F.	Pounds per U. S. Gallon at 60° F.	U. S. Gallons at 60° F. per Pound
30.0	7.296	0.13707	35.0	7.076	0.14132	40.0	6.87[illegible]	0.14557
30.1	7.291	0.13715	35.1	7.072	0.14140	40.1	6.866	0.14565
30.2	7.287	0.13724	35.2	7.068	0.14149	40.2	6.862	0.14574
30.3	7.282	0.13732	35.3	7.064	0.14157	40.3	6.858	0.14582
30.4	7.278	0.13741	35.4	7.059	0.14166	40.4	6.854	0.14591
30.5	7.273	0.13749	35.5	7.055	0.14174	40.5	6.850	0.14599
30.6	7.269	0.13758	35.6	7.051	0.14183	40.6	6.846	0.14608
30.7	7.264	0.13766	35.7	7.047	0.14191	40.7	6.842	0.14616
30.8	7.260	0.13775	35.8	7.042	0.14200	40.8	6.838	0.14625
30.9	7.255	0.13783	35.9	7.038	0.14208	40.9	6.834	0.14633
31.0	7.251	0.13792	36.0	7.034	0.14217	41.0	6.830	0.14642
31.1	7.246	0.13800	36.1	7.030	0.14225	41.1	6.826	0.14650
[illegible]	7.242	0.13809	36.2	7.026	0.14234	41.2	6.822	0.14659
	[illegible]237	0.13817	36.3	7.021	0.14242	41.3	6.818	0.14667
		0.13826	36.4	7.0[illegible]		41.4	6.814	0.146[illegible]
							[illegible]810	

132.58

Figure 13-17. — Portion of Table 8, ASTM-D1250 Petroleum Measurement Tables.

The method of converting the quantity from gallons to barrels is shown in figure 13-16.

WEIGHT CONVERSION

In many ports outside the United States, fuel oil is sold on a weight basis of tons or other weight standards. In arriving at the weight delivered, the specific gravity at 60° F is generally used, but this temperature may vary in some areas. When quantity is computed on a weight basis, volume determinations computed in accordance with figure 13-15 will first be made and subsequently converted to the designated weight standard in accordance with the abridged ASTM-D1250, Table 8, a portion of which is shown in figure 13-17. An example of weight calculation is shown in figure 13-18.

140,420 × 7.030 = 987,153

Gallons of Product received

Pounds per Gallon corresponding to API Gravity at 60°F as taken from Table 8, ASTM-D1250 Petroleum Measurement Tables (API Gravity 36.1 at 60°F.)

Pounds of Product received

10.32.0

Figure 13-18. — Example of weight calculation.

SAMPLING

Correct sampling procedures are necessary to provide truly representative samples that are used primarily for determining the physical and chemical properties of products. In this connection, sampling is an important phase of quality surveillance. Correct sampling procedures are also required to provide samples used for obtaining the gravity and the suspended water and sediment of the product, both of which are required for computing volume accurately.

TYPES OF SAMPLES

The portions taken for samples must represent the general character and average condition of the lot being sampled. Various types of samples may be taken. Among the more common types are: average samples, upper samples, middle samples, lower samples, and composite samples.

An AVERAGE SAMPLE is one so taken as to contain parts from all sections of the container or pipe, in proportion to the volume of each part. However, it is practically impossible to obtain a true average sample, except perhaps, through a continuous sampling connection from a vertical run in a pipeline with specially constructed draw-off pipes, or by vigorously agitating and stirring the contents of a vessel and drawing off a sample while the contents are agitated.

An UPPER SAMPLE is one taken from the upper third of the fluid (at a point taken from the percent of the depth of a uniform cross-section vessel, or 10 percent of the diameter of a horizontal cylindrical tank).

A MIDDLE SAMPLE is one taken at half the depth of the material.

A LOWER SAMPLE is one taken at a point 10 percent of the depth of a uniform cross-section vessel, or 10 percent of the diameter of a horizontal cylindrical tank, above the bottom of the vessel.

A COMPOSITE SAMPLE is a mixture of upper, middle, and lower samples containing, for vessels of different shapes, volume proportions which correspond approximately to the volumes of the material at these levels:

For uniform cross-section vessels: upper sample, 1 part; middle sample, 3 parts; lower sample, 1 part.

For horizontal cylindrical tanks (assumed full): upper sample, 1 part; middle sample, 8 parts; lower sample, 1 part.

For horizontal cylindrical tanks that are only partially filled, these sampling levels and composite sample mixtures cannot give samples that are substantially proportionate to the volumes at the different depths unless the tanks are filled to at least 80 percent of the diameter. Table 13-1 gives a set of substantially correct sampling levels and sample quantities for partially filled horizontal tanks, which may be used, employing values in the tabulation that lie nearest to the actual filling depth.

SAMPLING PROCEDURES

There are a variety of sampling procedures, each of which is suitable for sampling a number of specific products under definite storage, transportation, or container conditions. One common method is discussed briefly below.

Customarily, samples are drawn from ship tanks, barges, and large shore tanks by lowering and raising a bottle while allowing it to fill. Glass bottles ranging from 1 quart to 1 gallon capacity are commonly used. (Metal containers, constructed with a bail are sometimes used.)

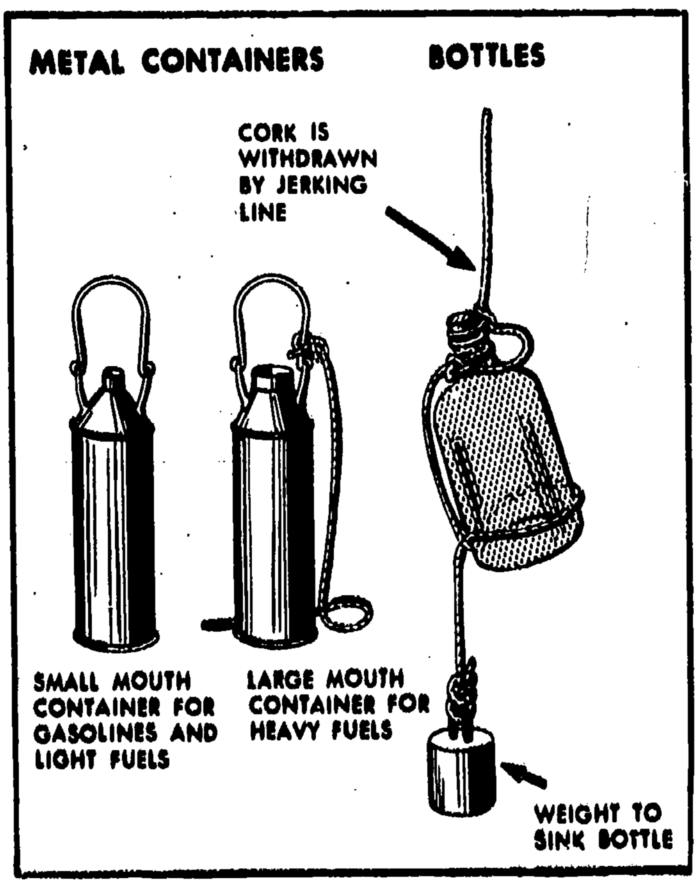
Table 13-1. —A Set of Substantially Correct Sampling Levels and Sample Quantities For Partially Filled Horizontal Tanks

Liquid depth (percentage of diameter)	Sampling level (percentage of diameter above bottom)			Quantity of sample to be taken at each sampling level		
	Upper	Middle	Lower	Upper	Middle	Lower
10	.....	.....	5	......	....	10 parts.
20	.....	.....	10	......	....	Do.
30	.....	20	10	......	6 parts	4 parts.
40	.....	25	10	......	7 parts	3 parts.
50	.....	30	10	......	8 parts	2 parts.
60	55	35	10	1 part.	....do....	1 part.
70	65	40	10	...do.	....do....	Do.
80	75	45	10	...do.	....do....	Do.
90	85	50	10	...do.	....do....	Do.
100	90	50	10	...do.	....do....	Do.

132.58.0

Sampling bottles are suspended in the tank by a cord tied to the cork and secured around the neck with two clove hitches, slack being allowed between cork and bottle as shown in figure 13-19. The free end of the line below the neck of the bottle is looped in a hitch around the lower part of the bottle and terminates in a lead weight heavy enough to sink the entire assembly. When the bottle is lowered to the desired depth (usually near the bottom of the tank, but above any water line), the cork is readily withdrawn by jerking the line. The bottle is then raised steadily at such a rate that it is not quite full when it breaks the surface. Samples obtained in this way are considered to be average samples, but obviously the proportions are not related to the tank volume at the various levels.

During sampling, every precaution must be taken to ensure that the sampling apparatus and the samples themselves are neither contaminated nor altered by any material not representative of that being sampled. The sampling apparatus should be thoroughly clean, dry, and free from any substance that will dissolve into or color the product being sampled. Before the sample is drawn, the sample container must be rinsed with the product being sampled, taking special care to ensure that no lint or fibrous material is present. After collection of the sample, the container must be closed immediately.



132.60

Figure 13-19. —Sampling containers.

DISPOSITION OF SAMPLES

Samples are used for one or more of the following purposes:

1. Visual examination
2. Laboratory test
3. Preservation for record
4. Check and referee tests

RETAIN samples are held for the protection of the supplier, loading terminal, and inspector. These samples are marked, showing the sources of the sample and the date taken. They are then stored and held for the length of time prescribed for the particular product.

SAFETY

A number of safety precautions relating to the handling and storage of petroleum products have been given in preceding portions of this chapter. Additional safety measures, and information on the hazards involved in working with petroleum products, are presented below. Note that chapter 14 deals with hazards and precautions applicable to the cleaning of fuel storage tanks. Various precautions in chapter 14 may also apply to duties that involve the handling and storage of petroleum products.

Because of hazards involved in the widespread use of gasoline and other petroleum fuels and the varying circumstances under which they are handled, it is important that thorough instructions be given all personnel concerning these dangers and the methods of preventing fires and explosions.

FLASH POINT

The hazards of handling petroleum products are related to flash point. The flash point of a liquid is the lowest temperature at which it gives off vapor near the surface of the liquid or within a vessel in sufficient quantity to form flammable mixtures with air. Products which give off flammable vapors at or below 80° F, such as gasoline, solvents, and most crude oils, are the most hazardous of all petroleum products to handle. For example, gasoline has a flash point of about 45° and crude oil has a flash point of 60° F. Certain petroleum products are slightly less hazardous to handle, such as kerosene, light and heavy fuels and lubricating oil, which have a flash point of about 115° F and will not ignite at ordinary atmospheric temperatures—but if heated above 110° F, they will give off sufficient vapors to burn and may explode under certain conditions.

FUEL OIL VAPOR

Fuel oil itself is nonexplosive, very difficult to ignite in bulk, and is not normally capable of spontaneous combustion. The vapor from this oil, however, is explosive when mixed with air in certain proportions. This vapor is heavier than air and tends to accumulate in low levels, such as bilges and bottoms of tanks, where it may remain undiscovered until ignited by a naked light or spark.

Vapor is always present in a partly filled tank or in one that has contained fuel oil or other petroleum products unless the vapor has been removed by artificial means. It is expelled through the vents from such tanks while they are being filled.

A fuel leak allowed to continue in any part of the fuel-burning system may result in an accumulation of enough vapor to form an explosive mixture with the air.

Portable vapor-indicator instruments have been developed for detecting the presence of petroleum vapors. A vapor indicator is described in chapter 14 of this manual. Vapor indicators should be freely utilized, not only for detecting vapors during cleaning operations discussed in chapter 14, but also for detecting vapors in cofferdams, voids, and storeroom spaces in which oil leaks occur, or in which vapor is suspected to have collected.

CONTROLLING VAPORS

In your efforts to control vapors, take care that no spills occur. Avoid spills from overflow when loading storage tanks by gaging tanks prior to loading. If spills occur, clean them up immediately, following instructions given in chapter 14.

Never neglect leaks. Make frequent inspections for leaks in tank seams, tank shells, and pipe joints. All outlets from tanks, except vents, should be closed.

When temperatures are excessively high, cool storage tanks by sprinkling, or by playing water over them.

Keep gasoline containers, whether empty or full, closed tightly.

Beware of empty gasoline containers since vapors may be present.

Ensure proper ventilation of all enclosed spaces in which vapors may accumulate.

ACCIDENTAL IGNITION CAUSES

Ignition of the explosive mixtures may be caused by an open light, electric spark, static discharge, and opening any electric switch carrying current. Some of the precautions that should be observed to prevent the ignition of fuel vapors are given below.

While oil, gasoline, and other hydrocarbons are being received or discharged, naked lights, smoking and electrical apparatus liable to spark must not be permitted on board ship or within 50 feet of an oil hose, tank, compartment containing a tank, pump, or the vent from a tank. The carrying of matches or cigarette lighters on the person while at work loading, unloading, or cleaning tanks should be prohibited. Portable lights of all kinds should be explosion-proof in the vicinity of gasoline and vapor-proof in the vicinity of fuel oil. Their wires must be well insulated.

"No Smoking" signs and other appropriate visual warnings should be conspicuously posted in the vicinity of loading and handling of petroleum products and the cleaning of tanks.

No tugboat, locomotive, automobile, or other gasoline or diesel propelled equipment should be allowed to approach within 200 feet of loading operations unless specific approval is granted by appropriate supervisory personnel.

Personnel engaged in loading, unloading or cleaning tanks should not wear boots or shoes with exposed nails or metal fastenings. Do not allow any buttons made of sparking metal to be exposed. Beware of key chains, belt buckles, and tools in pockets. In highly hazardous areas, personnel are not permitted to wear outer or under garments made of wool, silk, or synthetic textiles such as rayon and nylon, as these materials can generate sufficient static electricity to cause ignition of highly flammable products.

Dangerous static charges are frequently accumulated and discharged in such a way that fires and explosions result unless proper precautions are taken.

Static electricity is produced when gasoline or similar flammable liquids undergo movement such as flow through a hose, agitation of petroleum liquid, or when poured from one receptacle to another or when passed through a filter.

Moving parts of machines, particularly in dry atmospheres, may cause static electricity. Grounding of machines prevents the accumulation of dangerous charges. Moving belts which are not electrically conductive, such as those employed for conveyors and power transmission, are also sources of static electricity. One method of combating this source is the use of rubber belting containing a conducting component.

The metal nozzle at the end of gasoline or other fueling hose should be bonded to the coupling which is attached to the pump by a copper wire inside the hose, and the nozzle should be held in contact with any metal tank or receptable which is being filled with gasoline. An induced charge of electricity of considerable voltage may be accumulated by the friction of fuel flowing through a metal funnel when loosely placed over the inlet of a container being filled. Therefore, the funnel should be in metallic contact with the supply outlet.

All metal receptacles, funnels, etc., used in the handling of gasoline should be in contact with each other or should be bonded together and grounded.

Never load or unload flammable products during electrical storms.

To avoid spontaneous ignition, use only self-closing metal receptacles for discarding oily waste and dispose of such collections daily.

Shut off gasoline tank-truck engines during the entire period of filling or discharging unless the truck is designed for engine operation to drive transfer pumps through a power take-off, or unless the truck is approved for using gasoline in engines for operating pumps.

Care must be taken that the flame arresters in the vent pipes from tanks are kept intact and smoking, sparks, or flames must not be permitted in the immediate vicinity of such vents. The flame arresters must be kept free from paint and accumulations of soot or lint.

HEALTH HAZARDS

First symptoms of exposure to toxic vapors are headache, nausea, and dizziness. If such symptoms are noted, they should be taken as warning of the presence of dangerous amounts of vapors in the air. Recovery from these early symptoms is usually prompt after removal to fresh air. However, if men are overcome by vapors, they should receive immediate medical attention. First aid consists of prevention of chilling and of the application of artificial respiration are covered in Standard First Aid Training Course, NavPers 10081-B.

Gasoline may cause skin irritations if allowed to remain in contact with the skin, particularly under soaked clothing or gloves. Clothing or shoes through which gasoline has soaked should be removed at once. Gasoline should be washed from the skin with soap and water. Repeated contact with gasoline removes the protective oils from the skin and causes drying, roughening, chapping, and cracking, and in some cases infections of the skin which may become serious.

Oil-resistant rubber gloves should be worn as protection by persons handling petroleum products.

Gasoline should NOT be used for cleaning purposes under any circumstances.

If a person swallows gasoline, first-aid should be given immediately. Give the victim a half cup of olive or cooking oil and several cups of strong coffee or tea. DO NOT CAUSE VOMITING. Medical attention should be obtained immediately.

KEEP INFORMED ON SAFETY

The above does not tell you all you need to know about the hazards involved in working with petroleum products, and safety precautions applicable to the handling and storage of these products. If you are assigned duties requiring the handling and storage of petroleum products, consult your supervising petty officer for additional information on the safety aspects of the job. Also refer to Government publications and books by private industry containing material on petroleum for pointers on safety in working with petroleum products.

CHAPTER 14

FUEL STORAGE TANK CLEANING

Each year the Naval Shore Establishment cleans hundreds of petroleum fuel storage tanks. The tanks involved include various sizes of surface steel tanks, underground steel tanks, and underground concrete tanks. Fuel stored in these tanks includes burner fuel oils, diesel oils, kerosene, and so on. There are inherent risks associated with the cleaning of any fuel storage tank. Regardless of the risks involved, however, tanks may be cleaned safely if proper methods and techniques are used and if adequate safety precautions are observed. The hazards involved can be separated into three major classifications: fire or explosion, health, and physical. We will discuss each of these classes of hazards. We will also take up tank cleaning methods and procedures. Before getting into the subject of hazards and cleaning methods, though, we will explain a few factors concerning vapor-freeing.

VAPOR-FREEING

The term "vapor-freeing" refers to a process that is inherently associated with practically all tank cleaning projects. It involves the removal of hydrocarbon (fuel) vapors from a tank after the liquid fuel has been removed. Vapor-freeing is usually accomplished by exhausting vapors to the atmosphere through use of mechanical or natural ventilation. However, it may be accomplished by other means. (Methods of vapor-freeing are explained in later portions of this chapter.) A tank which is "vapor-free" or "gas-free," or which has been "vapor-freed" or "gas-freed," is a tank which has had fuel vapors removed.

One of the most important items in tank cleaning projects is to determine if conditions are safe, not only from the fire or explosion standpoint, but also from the health standpoint. The COMBUSTIBLE VAPOR INDICATOR, illustrated in figure 14-1, is the instrument which will, in most instances, provide necessary information for making this determination. This instrument is also known as a GAS INDICATOR, EXPLOSIMETER, or VAPOR INDICATOR.

The combustible vapor indicator is used to measure the approximate concentration of flammable fuel vapors in air. It will indicate whether a flammable vapor-air mixture exists. And, it will indicate, from a fuel vapor toxicity standpoint, whether the air is safe to breathe. The combustible vapor indicator, however, is not sensitive enough to measure small concentrations of fuel vapors which may have a toxic effect upon a person if the vapors are inhaled for periods over 8 hours.

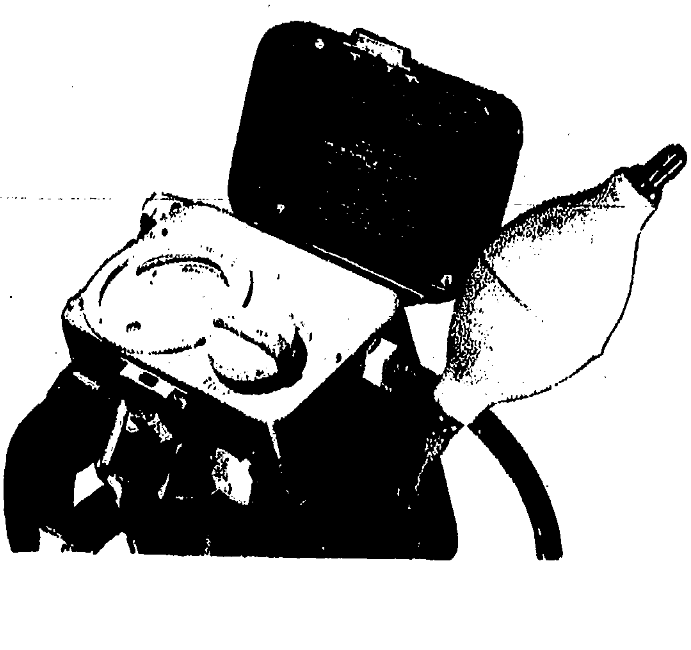


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Figure 14-1. —Combustible vapor indicator.

The dials of different indicators may not be the same. On all dials, though, the needle will point directly to the proportion of flammable vapors from 1 percent to 100 percent of the lower flammable limit, when the instrument is calibrated to the specific vapor being sampled. (See fig. 14-2.) When the vapor concentration is greater than the lower flammable limit, the needle will drop back to zero after going off the scale. Thus, it is essential to constantly watch the needle as tests are being conducted.

You must remember that there are some vapors and gases which the combustible vapor indicator will not detect. It will not detect tetraethyl lead (abbreviated TEL) vapors; in fact, it may become inoperative if exposed to concentrated amounts of these vapors. It will not detect nonflammable gases which are toxic, nor will it indicate if a vapor is toxic.

Several brands of combustible vapor indicators are available. But all those in common use operate on the same basic principle, that principle being the catalytic behavior of a coiled platinum filament that is heated. A sample of air is drawn into the instrument and the flammable portion is ignited by means of a catalytic filament (heated platinum filament). The filament is part of a balanced circuit supplied with current by flashlight batteries. Increase of resistance in the filament unbalances the circuit and causes deflection of the instrument needle. The richer the concentration of fuel vapor in the sample, the higher the heat generated when ignited, and the increase in resistance to the heat produced will cause a larger deflection of the instrument needle. Many companies ensure that the combustible vapor indicator is in good working order by testing the instrument in a known vapor area. Between tests, the instrument should be cleared by flushing with fresh air.

To be reliable, combustible vapor indicators must be maintained and used properly. They must be calibrated properly to give true readings. The flashlight cells in the instrument must not be exhausted. Furthermore, there must be no mechanical failure of any parts. True readings will not be obtained if liquid is drawn in with the vapors.

The combustible vapor indicator must be used only by personnel who have been properly trained in its operation. Unless the manufacturer's operating instructions is in the hands of an untrained person, the indicator can be a dangerous tool by giving incorrect readings, which will result in a false sense of security. All indicators should be listed by Underwriters' Laboratory, Inc. as being safe for use.

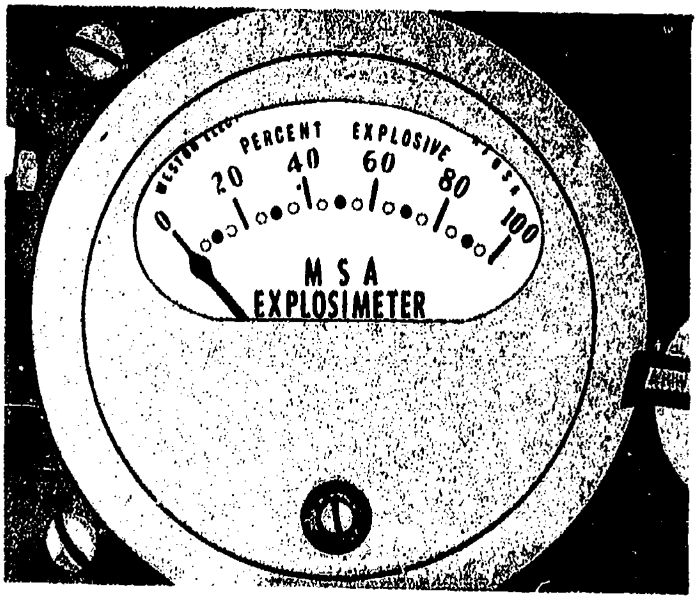

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Figure 14-2.—Dial of combustible vapor indicator.

FIRE AND EXPLOSION

The fire or explosion hazards inherent in the handling of petroleum fuels are of primary concern. If these hazards are recognized, understood, and treated accordingly, the possibility of a fire or explosion is minimized or eliminated.

ELEMENTS OF COMBUSTION

To cause a fire or explosion, three essential elements must be present at the same location and at the same instant. These elements are fuel (flammable vapor), air (oxygen), and heat (source of ignition). In addition, the proportion of fuel vapor to air must be within certain limits. To prevent a fire or explosion, one or more of the three elements of combustion must be controlled.

When anything burns, FUEL in the form of vapor must be present. It is not the actual substance which is consumed by the flame, but the vapor of the substance in combination with the oxygen of the air. For example, a piece of wood held in a flame will not catch fire until it has been heated to a point where vapor is given off. Some petroleum products give off sufficient vapors at normal handling temperatures to form flammable vapor-air mixtures; therefore, these products constitute greater fire hazards at normal handling temperatures than those with high flash points. It must be remembered, however, that fuel oil, or any other combustible liquid, when heated to or above its flash point, will produce sufficient vapor to form flammable vapor-air mixtures.

AIR must be present, and mixed in suitable proportion with the fuel vapor to form a mixture which can be ignited. Vapor without sufficient air, or with an excess of air, cannot be ignited.

In order to ignite a vapor-air mixture, HEAT of sufficient temperature must be present, such an an open flame, or an electric spark with sufficient energy.

CHARACTERISTICS OF FUEL VAPORS

Under normal conditions of handling and temperature, volatile fuels vaporize rapidly, and flammable vapor-air mixtures form above the liquid surface if there is sufficient air. The extent of flammable vapor-air mixtures formed, and the distance above the liquid at which they exist, are dependent upon the volatility of the product, the area of the liquid surface, and ventilation or air movement above the liquid.

In an open area free of pits and depressions, or in a freely ventilated area, fuel vapors disperse rapidly. Within a short period of time, "rich" and flammable vapor-air mixtures become diluted with air to concentrations below the lower flammable limit, but in doing so must pass through the entire flammable range. Obviously, the greater air movement in an open area or in an area ventilated to the atmosphere, the more rapid the vapor disperson.

When volatile fuels and/or its vapors are in a confined area where ventilation is restricted, "rich" vapor-air mixtures will probably exist. This condition will continue to exist until all fuel has vaporized and vapors have been removed.

Fuel vapors are heavier than air. They will settle in low places, such as depressions and pits, and, depending primarily upon air movement, the vapors may remain there as a hazard for a considerable length of time. Unless removed, fuel vapors will remain in tanks indefinitely after removal of the fuel.

When large quantities of fuel vapors are released to the atmosphere, as might be the case in tank cleaning projects, the vapors may travel along a current of air or along a ditch or other depression. As a result, flammable vapor-air mixtures may form a considerable distance from the source of emission. If the mixtures are ignited, the flash may travel back to the source, causing a fire or explosion at the point.

VAPOR-AIR MIXTURES OUTSIDE OF TANKS

Leaks or spills, or vapors emitted from a tank during the vapor-freeing process, may result in the formation of hazardous vapor-air mixtures outside of the tank. The mixtures are most likely to exist in pits, enclosures, and depressions. They may not be in the flammable range at a specific time. However, due to fuel vapor characteristics and air currents along with other atmospheric conditions, the mixtures may quickly reach the flammable range if their vapor concentrations exceed 20 percent of the lower flammable limit. Therefore, from the standpoint of accidentally introducing a source of ignition, the "safe limit" for vapor concentrations outside of a tank has been established at 20 percent of the lower flammable limit.

Vapors From Leaks or Spills

When a volatile fuel leaks from a container, or is spilled, the resulting vapors almost immediately form flammable vapor-air mixtures. If the leak or spill occurs in an open area, or in a freely ventilated area, the flammable vapor-air mixtures are usually of short duration, and exist only near the surface of the liquid leak or spill. They cease to exist shortly after all the liquid has vaporized. If the leak or spill occurs in an area where dispersion and/or ventilation is restricted, vapors will exist until removed by such means as ventilation.

Where nonvolatile fuels are concerned, the liquid from leaks or spills will not, under normal conditions, vaporize in sufficient quantities to form flammable vapor-air mixtures. If, however, fuel sprays result from breaks or gasket failures in systems under pressure, the fuel may be broken down to such an extent that the finely divided particles assume the characteristics of vapor. Under these conditions, flammable mixtures may form.

Every effort must be made to prevent leaks and spills of fuels. Fuel distribution systems in the vicinity should be inspected throughout tank cleaning operations to assure that there are no leaks.

If leaks or spills of a volatile fuel occur, sources of ignition must be made toprevent leaks area. If the fuel involved is a nonvolatile one, tests should be conducted with the vapor indicator, and sources of ignition must also be excluded from these areas unless the tests indicate safe conditions.

Personnel entering the area of a leak or spill, for purposes of cleaning it up, testing, or otherwise, must be protected as necessary against the inhalation of toxic vapors.

Leaks or spills must be cleaned up immediately, and steps should be taken to prevent recurrence. Ground that has been soaked with fuel must be scraped, and the fuel saturated soil removed to a safe location; or the ground must be washed with water, or covered with sand or dry earth. Pits or other enclosures in which leaks or spills of volatile fuels have occurred must be ventilated so that vapors are dispersed. To reduce the potential sources of ignition that are associated with the presence of personnel, all personnel must be kept out of the vicinity until tests with the vapor indicator show that the vapor concentrations are within safe limits from fire or explosion — 20 percent or less of the lower flammable limit.

Vapors Emitted From Tanks

When a tank is vapor-freed, hazardous vapor-air mixtures may form in areas outside the tank. Where nonvolatile fuels are involved, it is not likely that hazardous mixtures will be formed. However, this must be verified by test with the combustible vapor indicator before relaxing any precautions against fire or explosion.

The type of fuel, method and rate of vapor-freeing, terrain, dikes, walls, and atmospheric conditions all have effects on the formation and extent of hazardous mixtures outside a tank. Potentially dangerous areas will vary with the conditions. Under some conditions, hazardous mixtures may not exist at all, or they may exist only in areas a few feet from the source of vapor emission; under other conditions, they may exist a considerable distance from the source of vapor emission. Therefore, from the standpoint of unnecessarily restricting operations within large areas surrounding a tank being vapor-freed, it is not practical to establish "set" criteria on safe distances involved — each tank cleaning project must be considered on its own. As a general rule, flammable vapor-air mixtures during vapor-freeing are not likely to exist at distances greater than 100 feet from the source of vapor emission. In making initial estimates of potentially dangerous areas, sound judgment must be used in conjunction with this general rule. It is emphasized that estimates must be made on the safe side — estimated distances to which hazardous mixtures may extend can always be reduced if tests during vapor-freeing indicate safe areas.

Prior to vapor-freeing a tank, it should be determined if hazardous mixtures might possibly exist outside the tank during vapor-freeing. Hazardous mixtures are considered to exist in any tank that has contained a volatile fuel. For any tank that has contained a nonvolatile fuel, the tank atmosphere must be tested for vapor concentrations. If the tests indicate concentrations in excess of 50 percent of the lower flammable limit, hazardous mixtures are considered to exist in the tank.

If it is determined that hazardous mixtures may exist outside the tank, an estimate of the limits of potentially dangerous areas should be made. All areas within a minimum radius of 100 feet from the exhaust manhole must initially be considered potentially dangerous areas. Allowance may be made for prevailing winds by reducing the 100-foot distance on the upwind side. All pits, pumphouses, sumps, enclosures, depressions, and areas outside of dikes, that are within a minimum distance of 200 feet on the downwind side of the exhaust manhole, must be considered potentially dangerous areas. Warning signs, if not already in existence, must be placed at appropriate locations around these areas, and sources of ignition must be excluded therefrom when commencing vapor-freeing.

During the vapor-freeing period, tests with the combustible vapor indicator must be conducted in all potentially dangerous areas. Initial tests must be conducted 30 minutes after vapor-freeing commences. Tests should be conducted thereafter at 30-minute intervals. When readings obtained in an area indicate no vapor concentrations, or that vapor concentrations are 20 percent or less of the lower flammable limit, and have been continuously decreasing, no further tests need be conducted in that area unless (1) the vapor eduction rate from the tank increases or (2) there is a change in atmospheric conditions. When wind direction changes during the period of vapor-freeing, or when the vapor eduction rate from the tank is increased, new areas of potential danger must be established and tested for vapor concentration.

If at any time during the vapor-freeing period vapor concentrations in an area exceed 20 percent of the lower flammable limit, the following actions should be taken:

1. Sources of ignition that may have been in the area must be removed.
2. Personnel, unless necessary to carry out an operation, must be excluded from the area. When personnel must enter the area, they should be protected as necessary against inhalation of the toxic vapors.
3. If the area involved is other than an enclosed area, the vapor eduction rate from the tank should be reduced or vapor eduction should be stopped. Vapor-freeing must not be resumed in the normal manner until vapor concentrations in the area are 20 percent or less of the lower flammable limit.
4. If the area involved in enclosed, ventilation must be provided to reduce vapor concentrations.

VAPOR-AIR MIXTURES INSIDE OF TANKS

Vapor-air mixtures will exist in any volatile fuel storage tank as long as any fuel or fuel-soaked material remains in the tank. Further, the mixtures will continue to exist, even after removal of the vapor-emitting material, until the tank has been vapor-freed. At one time or another the mixture will probably be within the flammable range. Where nonvolatile fuels are concerned, vapor-air mixtures may also exist, but it is doubtful if they will be in the flammable range.

After a volatile fuel has been removed from a tank, the tank may contain a vapor-air mixture too "rich" to be ignitable. Such mixtures may be ignited and burn at points of escape; namely at manholes or other openings where air is present to sufficiently dilute the "rich" vapors. Upon providing air to ventilate the tank, the incoming air will dilute the "rich" vapors and the vapor-air mixture in the tank may quickly reach the flammable range.

After a tank has been freed of vapor, flammable mixtures may again be formed. They may be formed by the admission of vapor or fuel from an unblanked line or from a hole in the tank bottom or shell; or they may be formed as a result of vapors released from sludge, sediment, sidewall scale, hollow roof supports, or absorbent materials in the tank. Even though a tank atmosphere is being maintained in a nonhazardous condition through the process of vapor-freeing, the stirring up of fuel-soaked residue in the tank may release additional vapors faster than they can be removed from the tank; thus, flammable vapor-air mixtures may exist until the rate of vapor-freeing catches up with the rate of vapor release.

For a tank to be in a condition that is "safe for explosion," from the standpoint of accidentally introducing a source of ignition, the vapor concentration in the tank atmosphere must be maintained well below the lower flammable limit. SAFE FROM EXPLOSION means that vapor concentrations in the tank atmosphere, when tested with the combustible vapor indicator, must not exceed 50 percent of the lower flammable limit. Safe from explosion does NOT imply that the tank atmosphere is safe to breathe, nor does it imply that it is considered safe to purposely introduce a source of ignition.

A tank that has contained a nonvolatile fuel will probably be safe from explosion not only initially, but through all phases of tank cleaning; if it is not, it should be relatively easy to vapor-free it to, and maintain it in, such a condition.

For a tank that has contained a volatile fuel, making it safe from explosion will require not only vapor-freeing, but will probably require removing the bulk of any remaining fuel and other vapor bearing material in conjunction with vapor-freeing.

As a general rule, it will be possible to make nonvolatile fuel storage tanks safe from explosion before personnel entry. This same general rule will hold true for surface tanks that have contained volatile fuels. For underground tanks that have contained volatile fuels, however, it may not be possible, or feasible, to do this. Determining factors will be the time involved to reduce vapor concentration, the size of the tank, the amount of fuel and solid residuals, and the methods and facilities available for floating and removing fuel, hosing down the tank, and removal of solid residuals. As an example, it would not be feasible to try and float residual fuel for the purpose of removing it unless (1) there is sufficient water available, (2) the water could be admitted to the tank in a safe and easy manner, and (3) the floating fuel and water could be removed within a reasonable length of time.

As another example, in connection with the removal of solid residuals, it would probably be impossible to adequately hose down a large diameter tank from a single roof manhole.

When it is not possible or feasible to make a tank safe from explosion prior to entry of personnel, protected personnel must enter it to push or flush the bulk of residuals into an area where they can be removed by pump or by other means.

Under emergency conditions, it may not be possible to vapor-free a tank to safe limits before repairs must be made. If the repairs involved necessitate the introduction of ignition sources, the vapor-air mixture in the tank can be, and must be, made nonflammable. This may be accomplished by allowing an inert gas, such as nitrogen or carbon dioxide, to fill the vapor space in the tank, thus making the vapor-air mixture too lean to be ignited. Repairs involving welding may be safely accomplished by filling the entire tank with water and performing the welding below the waterlevel.

Before any tank cleaning operation commences, all fuel possible must be drained or pumped from the tank through use of existing connections.

All tanks must be made safe from explosion before entry of personnel is allowed, unless it has been determined that it is not possible or feasible to do so. If it is determined not possible or feasible to vapor-free a tank to safe limits before personnel entry, personnel may enter the tank to effect removal of vapor bearing materials. Such a determination must not be made, however, until all possible and feasible steps have been taken to remove vapor bearing residuals in the tank. Possible and feasible steps taken should include the following, and in the order listed:

1. After removing all fuel possible through use of existing connections, remaining fuel must be removed to the maximum extent possible through use of the tank sump pump or portable pump.

2. Residual fuel, if existent in other than insignificant quantities, must be floated with water and removed if: (a) sufficient water is available, (b) the water can be admitted to the tank at or near the floor of the tank, (c) the water can be admitted through use of the existing pipeline distribution system, and (d) if the floating fuel and water can be expeditiously removed.

3. If step 2 above can be accomplished, residual solids must then be removed by hosing down the tank from an open manhole and removing the resulting mixture if: (a) the water stream from the hose is capable of reaching the far side of the tank with sufficient force to dislodge and wash residuals from that area, and (b) if the water-residue mixture can be expeditiously removed.

Under conditions where it is possible to make a tank safe from explosion before entry of personnel, TESTS with the combustible vapor indicator should be conducted inside the tank at 15-minute intervals when personnel are in the tank. The tests should be conducted until there is no apparent danger of vapor concentration increases. If at any time vapor concentrations exceed 50 percent of the lower flammable limit, all personnel in the tank should leave. The tank should then be further vapor-freed; and if necessary to expedite vapor-freeing, residuals should be removed without entering the tank.

To preclude the possibility of fuel and/or flammable vapors entering the tank during cleaning operations, all fuel pipelines leading into and away from the tank should be drained. The valve nearest the tank on each of these lines should be removed, and the end of the line furthest from the tank should be blank-flanged, frequently referred to as BLINDED. Bear in mind that THE MERE CLOSING OF

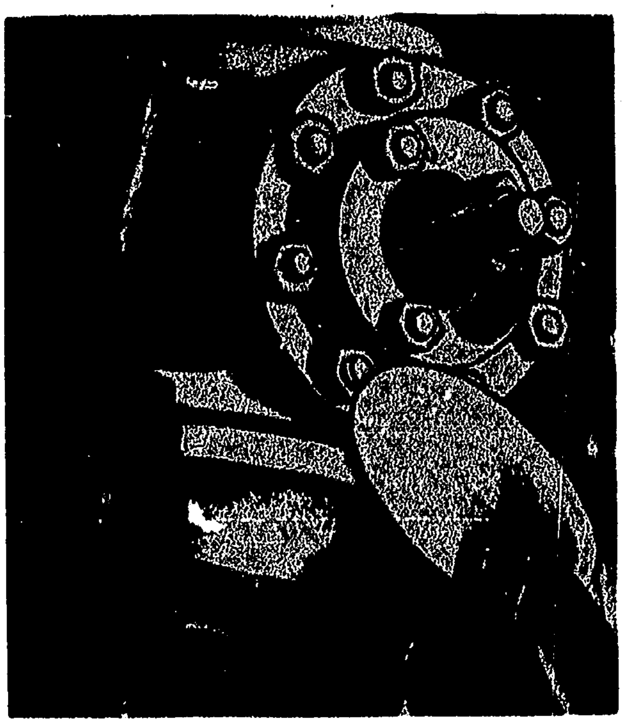

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Figure 14-3. — Blinding pipeline with "banjo."

VALVES TO EXCLUDE FUEL AND/OR VAPORS MUST NEVER BE RELIED UPON.

Instead of removing a valve to blank-flange the line, an alternate acceptable procedure for blinding lines that are 8 inches and smaller in size is to place a BANJO in the lines on the valve side which is nearest the tank (see fig. 14-3).

A banjo is a round, flat piece of metal with an arm; it is large enough to cover the inside diameter of the pipe, yet small enough so as not to interfere with flange bolts that are in place. To use a banjo, it is necessary to (a) close the valve, (b) remove bolts on the top and sides of the flange, (c) insert the banjo in the line between the flanges of the pipe and valve, and (d) replace and tighten all flange bolts.

Blank flanges, or any type of blind used, should be of sufficient strength to withstand any pressure to which subjected. Gaskets must be used with blank flanges to prevent leakage of the fuel.

In all cases where a tank initially contains a rich mixture, the tank atmosphere will pass through the flammable range during the vapor-freeing process. The length of time the flammable vapor-air mixture remains in the tank depends upon the speed at which the fuel vapors and vapor bearing materials are removed from the tank; therefore, vapor-freeing must be accomplished as quickly as possible to reduce duration of the hazard.

SOURCES OF IGNITION

It is possible, under almost every circumstance, to eliminate potential sources of ignition. Thus, even though flammable vapor-air mixtures do exist from time to time while cleaning tanks, the fire or explosion hazard can be controlled by excluding all possible sources of ignition from the area. In instances where the introduction of an ignition source is necessary to the operation being performed, such as welding, absolute assurance must be obtained that no flammable vapor-air mixtures exist during the operation.

Precautions should be relaxed to permit necessary equipment, such as trucks, compressors, and other devices, to be used without unreasonable restrictions in areas outside the tank which, even though at one time were dangerous, are no longer considered dangerous. Under no circumstances should sources of ignition be introduced into areas outside the tank if there is even a remote possibility of vapor concentrations increasing to greater than 20 percent of the lower flammable limit.

Open Flames and Excessive Heat

Hazards involving open flames and excessive heat include—but are not limited to—burning substances, hot exhausts, sparks from engine exhausts, and sparks and heat resulting from burning, cutting, or welding.

In regard to precautions, flamemaking devices and other potential sources of ignition must be excluded from areas where flammable vapors exist or where they may accumulate. As a warning of hazardous areas, NO SMOKING signs should be placed at appropriate locations. Personnel must not be allowed to carry matches and cigarette lighters into hazardous areas.

Gasoline-driven engines may be used to provide motive power for fans, blowers, and pumps. They must, however, be located on the upwind side of the exhaust manhole as long as there is a possibility that flammable vapor-air mixtures may accumulate outside the tank. This same precaution applies to motor-driven vehicles.

Electric Sparks and Arcs

Hazards that involve electric sparks and arcs include sparks from electric lamps, tools, fixtures, and appliances that are not explosion-proof; sparks from worn or defective electric extension cords; sparks from short-circuited electrical apparatus; and arcs or sparks resulting from opening or closing electric switching devices.

We should explain that, for purposes of this discussion, the term SPARK means "the passage of electric current across a gap between two points which have not been in contact"; this definition applies to electric sparks and also to static electricity sparks. The term ARC, as used in this discussion, means "the flow of electric current which occurs at the instant of separation of two points previously in contact."

Electrical equipment and wiring in areas of possible formations of flammable vapor-air mixtures must be explosion-proof.

When electrical equipment is located in areas where flammable vapors may accumulate, it must be grounded as necessary to prevent possible sparking.

All portable lanterns must be explosion-proof, Underwriters Laboratory approved, if they are to be used in areas where flammable vapor-air mixtures may exist. Flashlights are not considered a potential source of ignition and, therefore, there are no special requirements pertaining to them.

NOTE: Pneumatic tools and non-sparking tools should be used for any repair of fuel tanks which present a fire hazard.

Spontaneous Combustion

Oily waste, paint-soaked rags, and other materials that may give rise to spontaneous combustion are potential sources of ignition if left in the area of fuel and fuel vapors.

As a safety measure, materials capable of producing spontaneous combustion must be disposed of immediately. They should be placed in closed noncombustible containers that are frequently emptied, or in other safe locations.

Static Electricity Sparks

To ignite a flammable vapor-air mixture from static electricity sparks, there must be (1) static electricity generation, (2) accumulation of the static charges (electrostatic potential), and (3) discharge of the accumulated charges in the form of an incendiary spark while in the presence of a flammable vapor-air mixture.

As a safety measure, water must not be allowed to drop into a substantial amount of volatile fuel in a tank. Another precaution is to make sure that air, vapor, or steam at high velocities is not admitted into a tank containing flammable vapor-air mixtures. Nozzles used in conjunction with this must be grounded.

Stray Electrical Currents

Electrical currents, resulting from powerline leakage or galvanic action of the soil, should be assumed to exist in all buried piping systems. Tanks and equipment connected to the piping are considered part of the system, and should also be assumed to carry the same currents unless separated by insulating flanges. These currents rarely have sufficient potential to cause sparking. A hazard exists, however, from possible arcing, when the flow of current is interrupted by separating the pipeline. The arc resulting from this "contact breaking" is similar to the arc occurring when an electrical switch is turned off.

Prior to separating any portion of a fuel pipeline, removing any valve, or separating any other component from the fuel piping system including the tank, a heavy-gage bond wire ("jumper") should be attached to each side of the point where contact will be broken, if (1) there is no insulating flange at that point, and (2) if volatile fuels are involved. Thus the possibility of arcing will be reduced by allowing stray currents to continue flowing.

HEALTH HAZARDS AND PRECAUTIONS

There are health hazards associated with liquid fuels in themselves. The primary hazards, however, are associated with fuel vapors. Vapors from all petroleum products are toxic to the human body; and if received in sufficient quantity, serious illness or even death may occur. There are two approaches to the problem of making operations safe against health hazards during tank cleaning operations. The first approach is to make every effort to eliminate the hazards, or reduce them to such an extent that they will be negligible. After such an effort is made, and hazards still exist, the other approach, and the only remaining one, is to protect the individual himself against the hazards. It is emphasized that all health hazards associated with tank cleaning can be guarded against if proper protective clothing and equipment are utilized; therefore, if there is any doubt as to hazardous conditions present or hazardous conditions that may develop, adequate personnel protection against the condition must be provided.

LIQUID PETROLEUM FUELS (EXCLUSIVE OF LEADED GASOLINE)

Skin contact with fuel oils, diesel oils, and kerosene may not immediately irritate or be harmful—except in the sensitized or allergic individual. Continued contact with these fuels, however, may bring about irritation.

Gasoline on the skin will cause burns if it is allowed to remain in contact. Repeated skin contact with gasoline removes the protective oils from the skin, producing drying, roughening, chapping, and cracking. Skin infections may follow this damage. A severe irritation of the skin may develop, beginning usually at the place of contact and perhaps extending to other parts of the body.

Skin contact with jet fuels may not immediately irritate or be harmful; but, prolonged contact will probably lead to serious irritation. Any of the petroleum fuels in contact with the eye or an open-skin abrasion will probably prove irritating. Eye contact with fuel may result in damage to the eye.

Swallowing a small amount of any petroleum fuel will probably cause severe discomfort and illness. Ingestion (swallowing) of a large amount may be fatal.

An all-out effort should be made to provide adequate protection against health hazards of personnel engaged in tank cleaning operations. Some of the major precautions to observe are given below.

To eliminate the source of the hazard, or to at least reduce the extent, all fuel possible should be removed from the tank prior to personnel entry; thus, the possibility of skin or eye contact with, and ingestion (swallowing) of, the liquid is held to a minimum.

Body contact with petroleum fuels and fuel contaminated materials should be avoided. To protect the individual against such contact, protective clothing must be worn by personnel in tanks and pits and by personnel handling sludge topside. RUBBER GLOVES, solvent or acid-resistant, gauntlet type and first quality, and in good condition should be worn. Personnel working topside may wear gloves not of the gauntlet type, but they must be solvent or acid-resistant rubber throughout or other material coated with solvent or acid-resistant rubber. RUBBER BOOTS, solvent or acid-resistant, either hip or knee length, of first quality, and in good condition should be worn. Safety toes in the boots are recommended. Perhaps it should be pointed out that gloves and boots made of ordinary rubber may be used if solvent or acid-resistant synthetic rubber cannot be obtained. Ordinary rubber, however, disintegrates in contact with gasoline, and in disintegrating presents a spongy, slippery surface conducive to accidents. If used, it should be replaced as soon as possible with solvent or acid-resistant rubber.

GOGGLES, or an appropriate facepiece, should be worn when there is possibility of eye contact with fuel. COVERALLS, preferably light colored, are recommended for use. A skull CAP, painter's cap (or similar) also should be worn.

If at any time, clothing, whether protective or not, becomes soaked with fuel or sludge, the clothing should be removed promptly. Then a bath should be taken and clean clothing put on.

FUEL VAPORS (EXCLUSIVE OF VAPORS CONTAINING TEL)

The concentration of petroleum fuel vapors in air that can be inhaled and tolerated by man is far below that required to produce a flammable vapor-air mixture. The maximum lower toxic limit, sometimes referred to as "threshold limit" or "maximum allowable concentration" (MAC), is established at 500 parts per million (0.05 percent by volume). In spaces where maximum vapor concentrations do not exceed 550 parts per million, it is safe for personnel to work an 8-hour day without protection against inhalation of fuel vapors.

The measurement of fuel vapors in parts per million, as a direct reading on the combustible vapor indicator, is not possible—the indicator shows the amount of vapors as a percentage of the lower flammable limit. Since the lower flammable limit varies slightly with the fuel involved, the safe limit for inhalation of vapors in terms of direct readings, must be based upon those fuels which have the highest lower flammable limit. This limit is about 1-1/4 percent of some of the fuels encountered. Based on this, 500 parts per million is equivalent to 4 percent of the lower flammable limit.

Symptoms of Fuel Vapor Poisoning

Symptons of fuel vapor poisoning are similar to intoxication resulting from drinking alcoholic beverages; they include dizziness, nausea, and headache. Inhalation of concentrated amounts of petroleum fuel vapors acts as an anesthetic and may cause unconsciousness or death. As an example of the toxic effects produced by gasoline on some personnel, inhalation of 0.07-0.28 percent by volume of its vapors (equivalent to about 5.6-22.4 percent of the lower flammable limit) may cause slight dizziness after 3 minutes of exposure; inhalation of 1.13-2.22 percent by volume causes severe dizziness after 3 minutes of exposure; and inhalation of 2.20-2.60 percent by volume causes intoxication after 10 to 12 breaths.

Methods of Testing For Fuel Vapors

As pointed out earlier in this chapter, the combustible vapor indicator will, in most instances, provide the necessary information for determining if atmospheres are safe to breathe; it will not, however, provide information on existence of TEL vapors. The combustible vapor indicator is the instrument most commonly used in testing for fuel vapors in the atmosphere. Concentration of vapors in the atmosphere may be determined through chemical analysis; this process, however, because of the time involved and requirement for special equipment and trained technicians, is not generally used in tank cleaning projects. The flame safety lamp is intended for use in detecting oxygen deficiencies, and its use in atmospheres that may contain flammable vapors or gases is dangerous and strictly prohibited.

Precautions

One of the greatest health hazards during tank cleaning operations exists as a result of the presence of fuel vapors. Therefore, all tanks, and all pits or other enclosed areas where vapors exist, must be vapor-freed to the maximum extent possible and practical prior to entry of personnel.

Before entry of unprotected personnel into any area where vapors may exist, tests should be conducted with the combustible vapor indicator to determine the existence and amount of vapor concentrations. Entry of personnel into any area where vapors exist, regardless of the reason, should be allowed only under the three conditions given below.

1. Any area which contains vapor concentrations in amounts of 4 percent or less of the lower flammable limit is considered "vapor-free" or "gas-free." Men may work an 8-hour day in such areas without being protected against inhalation of toxic vapors, provided there is adequate ventilation.

2. In any area where vapor concentrations exceed 4 percent of the lower flammable limit, but do not exceed 20 percent, unprotected personnel may be therein provided (a) they do not stay for a length of time greater than 3 minutes, (b) there is adequate ventilation, and (c) they leave the area at the first signs of dizziness.

3. Unprotected personnel must not enter any area where vapor concentrations in the air to be breathed exceed 20 percent of the lower flammable limit. Protection against inhalation of toxic vapors must be provided.

It is pointed out that where the hazard from tetraethyl lead exists, tests, other than for TEL, will serve no useful purpose from a health hazard standpoint—the protective equipment which must be utilized as a precautionary measure against the TEL hazard will adequately protect the individual from other toxic vapor hazards or from a deficiency of oxygen. The tests, however, do serve the purpose of determining if an atmosphere is safe from fire or explosion.

Before any unprotected person is allowed to enter a tank for the purpose of testing or otherwise, tests for fuel vapors should be made with the combustible vapor indicator. The first tests should be made at the manhole where vapors are being emitted. When the indicator registers a safe condition, further tests should then be made in all accessible parts of the tank. Particular attention must be given to vapor pockets in the tank.

Upon entry of unprotected personnel into the tank, tests should be conducted at frequent intervals during the first 15 minutes. If vapor concentrations remain at a safe level, further testing need be conducted only at 15-minute intervals. Tests may be discontinued when there are no measurable vapors in the tank and there is no likelihood of vapor concentration increases. If at any time, vapor concentrations exceed safe limits, all personnel should leave the tank. Before personnel re-enter the tank, it should be further vapor-freed to within safe limits, or the personnel should be protected against inhalation of toxic vapors.

When protective equipment is not worn by personnel in the tank, there must be immediate departure from the tank of all personnel therein, at the first signs of anyone showing symptoms of dizziness, labored breathing, or excessive fatigue from slight exertion. Personnel must not re-enter the tank until it has been thoroughly ventilated and tested as being safe for entry, or unless the personnel are wearing protective equipment.

It is very important, of course, that care be exercised in testing areas other than tanks. Prior to entry, and after entry of unprotected personnel into any area where vapors may exist, tests should be conducted in the same manner and at the same intervals as when testing tank atmospheres. Unprotected personnel should immediately leave the area when vapor concentrations exceed safe limits. They should not re-enter unless protected, or until vapor concentrations have been reduced to safe limits.

Respiratory Protection

Respiratory equipment must be used by all personnel in areas where vapor concentrations exceed 20 percent of the lower flammable limit; it should also be used by personnel when they are in an area longer than 3 minutes, and vapor concentrations therein exceed 4 percent of the lower flammable limit.

To ensure that all nonmilitary respiratory equipment used by the Navy will afford the protection for which it is intended, only such equipment as is approved by the Bureau of Mines is used or authorized. The preparation of Navy specifications for all types of respiratory equipment takes into consideration the Bureau of Mines' requirements.

There are two main types of equipment suitable for use in the presence of toxic gases and vapors. They are: (1) fresh-air hose masks; and (2) the tank supplied air mask.

The fresh-air hose mask is designed to provide respiratory protection against oxygen-deficient atmospheres, and atmospheres that contain a high concentration of toxic gases and vapors. It can be used with a maximum of 150 feet of hose where the encumbrance of the hose line would not greatly interfere with the movement of the user. It is especially useful in entering tanks, tank cars, ship compartments, holds, and pipelines for inspections, cleaning, and repair work. The fresh-air hose mask may also be used for rescue work in recovering victims of irrespirable atmospheres.

As shown in figure 14-4 the fresh-air hose mask consists of a tight-fitting, full facepiece; breathing tubes; and a harness. The assembly also includes a noncollapsible hose line 1 inch in diameter, and hand-operated blower. The harness and hose are strong enough for retrieving the wearer in emergency, and the hose will not collapse under considerable weight. Moreover, it is so constructed that it will not kink and shut off the air supply. A dee ring is provided in the back of the safety belt harness for the attachment of a rope life line. The entire assembly of mask, hose, and blower is conveniently packed in a trunk for transporting and storage. (See fig. 14-5.) The use of a fresh-air hose mask in tank cleaning operations is mandatory. The mask is shown in figure 14-6.

The tank type air supplied mask equipment consists of a tank containing breathing air and a mask similar to the one used with the fresh-air hose line. The tanks can hold enough air to last from 15 minutes to 1 hour and are carried on the back of the wearer by a shoulder strap harness arrangement. Air is supplied to the face mask from the tank through a system of hose and regulating valves. This equipment

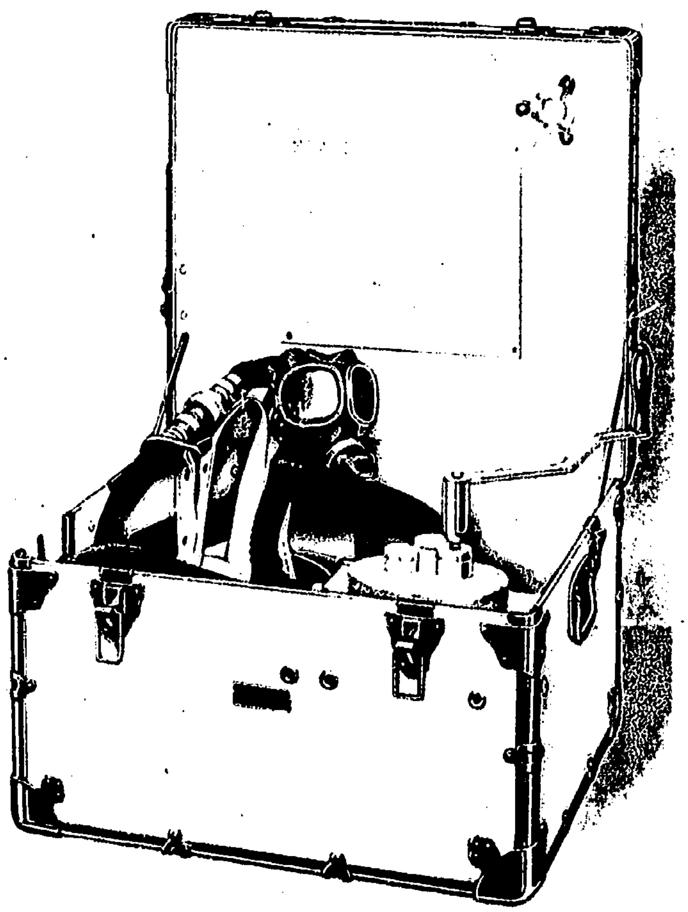

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Figure 14-5. — Fresh air hose mask unit.

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Figure 14-4. — Fresh air hose mask.

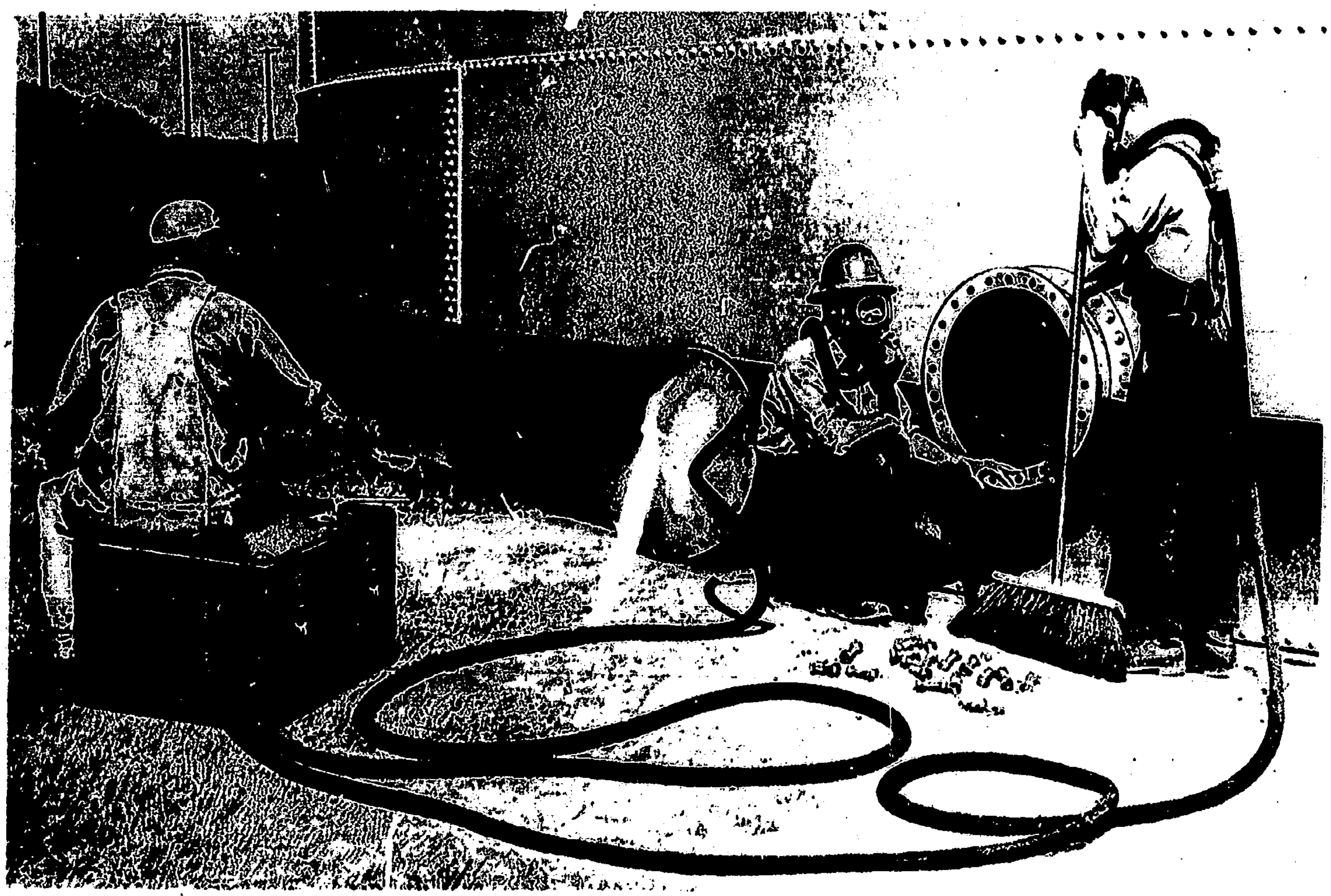

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Figure 14-6.—Use of fresh air hose mask in tank cleaning operations.

is very useful where the wearer is required to enter hazardous areas for short intervals such as in emergency rescue work.

A motor or hand-operated FRESH AIR BLOWER of the positive pressure type, Bureau of Mines approved, should be provided for each two masks. (See fig. 14-7.) The blower should be located so as to assure that fresh air only is admitted to the masks. It should be placed upwind and away from the exhaust manhole of the tank; its location should be where vapors or fumes from any source cannot enter the intake. Personnel on the blower detail should be cautioned about the necessity for maintaining a continual fresh air supply to the masks. Under no circumstances should the man who operates the blower leave the job unless he is replaced. An uninterrupted air supply to the masks must be maintained until all persons are out of the hazardous area and have removed their masks.

For each hose mask used, a SAFETY HARNESS also should be used. Attached to the harness should be a LIFELINE consisting of 1/2-inch rope that is of required length. A safety harness with attached lifeline is illustrated in figure 14-8.

You are probably familiar with the AIR-LINE RESPIRATOR, which is either a half-mask facepiece or a full facepiece supplied with fresh air through a small diameter (approximately 3/8 inch) flexible hose. The fresh air is supplied from a compressed air source, and the length of the air supply hose is limited to 50 feet. This type should NOT be used in tank cleaning operations.

CANISTER MASKS should NOT be used as protection against inhalation of petroleum fuel vapors—they will not properly protect the wearer against high concentrations of fuel vapors. Self-contained OXYGEN BREATHING APPARATUS (OBA) is a FIRE HAZARD and should NOT be used—they are cumbersome, petroleum vapors

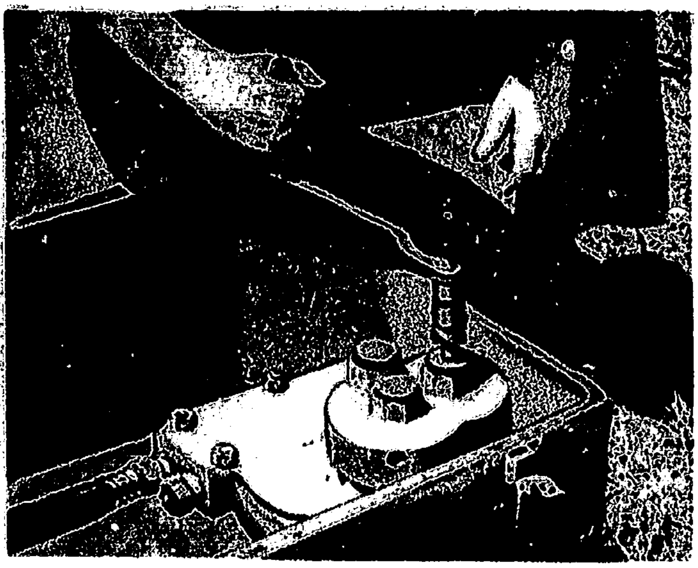

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Figure 14-7. — Fresh air blower.

adversely affect certain types, and there are time restrictions on their use.

All protective equipment should be INSPECTED, and TESTED if applicable, prior to use. Inspection and testing should be accomplished by, or under the supervision of, the tank cleaning supervisor. Some of the main items that should be covered when inspecting and testing the equipment are given below.

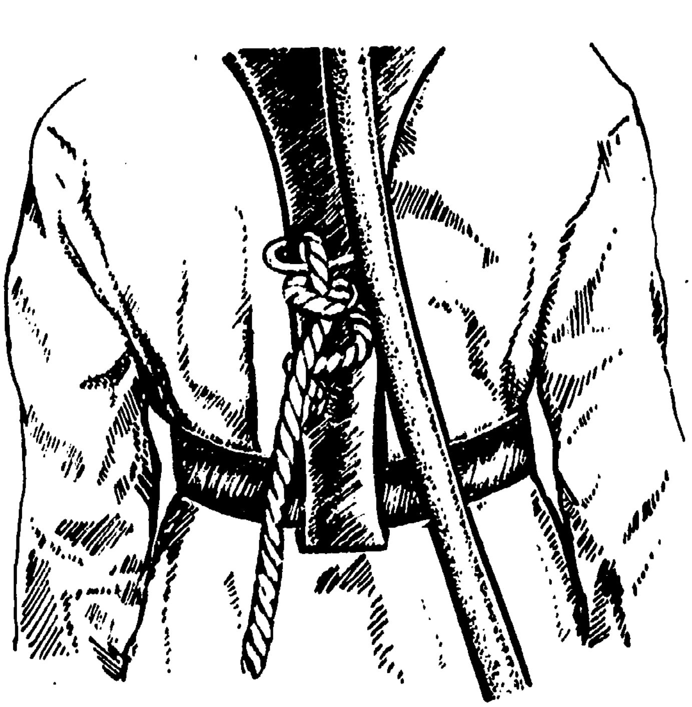

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Figure 14-8. —Safety harness with attached lifeline.

The fresh air blower must be tested for good operating condition prior to each use. The lifeline must be inspected for breaks, cuts, and frayed material. The harness should be inspected for weak material (cuts, cracks, and breaks), and for condition of "D" ring and buckle. If not satisfactory, the equipment must be discarded as unfit for use.

The hose mask and airhose should be inspected before each use to assure that both are in good condition. The mask should be checked for broken or cracked glass; worn, cut, or cracked rubber in the mask or mask hose; defective valve; defective head strap; loose connections on the mask hose; and restrictions in the mask hose. The airhose should be checked for breaks in the outside covering; defective gaskets; loose connections; and restrictions in the hose. If inspection reveals an unsatisfactory condition, the condition should be corrected before use; if it cannot be corrected, the defective equipment should be discarded as unfit for use.

In testing a mask, see that the mask (facepiece) is properly adjusted and tightened on the individual. The mask then can be tested for leaks by closing the end of the tube (mask hose) with the palm of the hand, or by pinching the tube, and inhaling. If the facepiece collapses against the face, the fit is satisfactory. If the facepiece does not collapse, a leak is indicated, which should be located and eliminated. In testing the mask, the user should remove his cap so as to enable a tight fit of the facepiece; the cap must then be replaced over the headstraps. After the mask has been tested for leaks, the airhose should be connected to the blower and then to the mask hose. Assurance should be obtained that the user of the mask is being supplied with sufficient air from the air hose and blower.

In USING PROTECTIVE EQUIPMENT, the following precautions should be closely observed:

Care must be exercised to prevent damage to equipment while in use.

Hose connections must be inspected frequently, and tightened whenever they become loose. Personnel should never twist or step over their hose line, as this may loosen connections.

If any person, while wearing a mask, notices an odor such as gasoline, he should leave the area immediately. The cause of odor should be determined; and if the hose or the mask can no longer be considered safe for use, it should be discarded and another one substituted.

Under no circumstances should anyone remove his mask while he is in an area which requires use of the mask. To lessen the possibility of mask removal, such articles as tobacco and chewing gum should be removed from the mouth prior to using the mask.

Protective equipment should be CARED FOR properly if it is to give efficient service in use. Three suggestions on caring for equipment are given below.

1. Masks should be thoroughly cleaned with soap and water, or their equivalent, followed by application of a mild disinfectant to prevent the possible spreading of germs or contagious diseases. They should be cleaned at least at the end of each day's use and upon completion of the job. A kerosene rinse, prior to washing with soap and water, will assist in removing fuel or sludge.

2. Upon completion of the job, all airhoses should be cleaned. The hose ends should then be capped, or joined, to prevent interior contamination.

3. After cleaning, all masks and airhoses should be dried, preferably by natural ventilation, and inspected for defects. The equipment should be protected against exposure to excessive heat.

Prior to entry into a hazardous area, personnel should be inspected for (1) proper clothing commensurate with the hazards involved, and (2) proper equipment, in good operating condition.

To avoid breathing vapors issuing from a tank, unprotected personnel removing manhole covers, or working around an open exhaust manhole, should keep on the upwind side as long as vapors exist.

PHYSICAL HAZARDS AND PRECAUTIONS

In addition to casualties which might result from fires or explosions, or from toxic conditions, injuries in the way of broken bones, head injuries, and internal injuries are possible when working in or around a tank. Proper instruction of personnel, the exercise of good judgment, and constant alertness on the part of the supervisor and all personnel associated with tank cleaning are essential to prevent injuries due to physical hazards. Some of the precautions applicable inside and outside of tanks are presented here. The precautions given are by no means considered to be all inclusive; they do, however, include the more important ones.

INSIDE OF TANKS

To prevent possible injuries to personnel inside the tank, precautions taken should include those listed below.

1. Tie up the swing line, if applicable, so that it will not drop.
2. Remove all loose objects from the upper part of the tank prior to cleaning operations.
3. Exercise care to prevent falling from scaffolding and ladders.
4. Equip ladders that may be used in the tank with nonskid-type bases.
5. Avoid stepping upon or across airhoses so as to prevent the possibility of tripping or of damaging the air hose.
6. Exercise care to prevent colliding with structural supports and pipes.
7. Provide sufficient light so that operations can be carried out without danger of colliding or tripping over unseen objects. Use explosion-proof lights inside tanks that have contained volatile liquids.
8. Exercise special care to prevent twisting or pulling airhoses around supports, ladders, or pipes.
9. Take care to avoid directing streams of water at personnel, or splashing sludge upon them.
10. Assure that lifelines and hoses do not become tangled.
11. Make certain that nothing is dropped into the tank from open manholes.
12. Ensure that no steam is admitted into a tank while personnel are therein.
13. Assure that no high pressure water streams are directed into the tank from a manhole while personnel are therein.
14. Check lines used for raising and lowering sludge buckets and tools to assure that there is no danger of their breaking.
15. Exercise caution when entering or leaving from the tank to avoid slipping and falling.
16. Assist personnel when they enter or leave a tank.
17. Make certain that lifelines and airhoses are "paid out" and "hauled in" as a person enters and leaves the tank.

OUTSIDE OF TANKS

Although usually less serious than inside the tank, serious hazards do exist outside of the tank. They exist primarily in the form of slipping and falling, or tripping and falling over hoses or pipes that may be in the vicinity of the manhole or between the manhole and the sludge pit. Precautions taken should include exclusion from the area of all items not essential to the operation, and exercising care to avoid tripping over such items as hoses, ropes, pipes, or tools.

GENERAL PRECAUTIONS

In addition to the precautions previously listed as applicable to a specific hazard classification; namely, (1) fire or explosion, (2) health, and (3) physical, there are various precautions which are of a general nature. Some of the important general precautions that should be carefully observed are pointed out below.

Men within a tank must be under constant observation of a responsible individual outside the tank. The observer should stop the job if conditions appear to be unsafe.

Sufficient help outside the tank should be available for rescue work in case of an emergency.

One or more persons qualified or trained in artificial respiration and simple first aid should be available outside the tank.

One extra set of protective equipment should be available at all times. Rescue operations can then be accomplished safely.

The number of men in the tank at the same time must be held to a minimum. No more than four is recommended, particularly if lifelines and fresh air line masks are used by the men.

Personnel should not be allowed to work continuously in a tank, without a break. Breaks in time should be given at least once every 2 hours. The actual length of time established for an individual may be less, depending upon his temperament and upon air temperature in the tank.

All work in the tank must be completed as soon as possible, so that personnel will be exposed to hazardous conditions a minimum length of time.

Only authorized personnel, essential to tank cleaning operations or inspections, should be allowed in the area during operations.

The supervisor should observe changes in wind direction if vapors exist outside the tank. He must relocate the air blower as necessary, if it is being used, to assure that only fresh air is admitted to the hose masks. He must relocate, as necessary, potential sources of ignition.

HAZARDS AND PRECAUTIONS RELATED TO TANK REPAIR

At times it may be necessary to enter a tank to repair or replace such items as swing lines, ladders, pumps, piping, tank bottoms, and tank linings. Such work usually requires tank cleaning and will require either hot work or cold work, or both.

REPAIRS INVOLVING HOT WORK

HOT WORK involves welding, flame cutting, the use of open flame equipment, or any other work where metal is heated to or above "red hot." The hazards encountered prior to actual accomplishment of hot work normally include all those previously given in this chapter. Associated with hot work in itself, there is danger from (1) fire or explosion resulting from the evolution of flammable vapors when material or residue, having been in contact with fuel, is heated, (2) ignition of combustible materials in the tank, (3) poisoning due to extreme heats encountered, (5) burns associated with hot work, and (6) shocks when arc-welding equipment is used.

Prior to undertaking hot work, the tank must be inspected by the chief in charge and/or fire chief. Hot work is the Steelworker's job, and generally the fire chief closely supervises this type of work. (Since hot work is not a function of the UT's job, detailed information on the subject is not given here.)

REPAIRS INVOLVING COLD WORK

COLD WORK involves any work not associated with intense heat or flame. Sandblasting or shotblasting, tank-lining repair, scraping, wire-brushing, and most all work in connection with tank cleaning is considered to be cold work. Some cold work in tanks may be accomplished without cleaning and vapor-freeing if appropriate precautions are taken. However, it is recommended that when possible, and prior to such work, the tank be cleaned and vapor-freed so that it will be safe for entry without protective equipment. The tank should always be within safe limits from a fire or explosion standpoint when blasting is accomplished; thus, even though sparks do occur, there will be no danger.

With the exception of hazards peculiar to a specific operation, such as might be encountered in the application of linings that contain flammable and/or toxic solvents, there are no additional hazards involved in most types of cold work that are not involved in tank cleaning. Therefore, all appropriate precautions given in the preceding paragraphs of this chapter should apply.

TANK CLEANING METHODS AND PROCEDURES

A project for the cleaning of any fuel storage tank may be considered to consist of five primary phases. They are (1) planning the operation, (2) preparation for cleaning, (3) vapor-freeing the tank, (4) cleaning the tank, and (5) cleanup, inspection and acceptance. Each phase will be considered separately below. You may not find all you need to know about tank cleaning methods and procedures. But the information given should, at least, be useful as a guide to personnel engaged in the performance of supervision of tank cleaning projects.

PLANNING THE OPERATION

The importance of good planning for the accomplishment of tank cleanings cannot be overemphasized. Planning is reflected throughout most all operations; improper planning, in this instance, may result in property damage and/or personnel casualties.

An important step in planning a tank cleaning project is to establish the reason for cleaning. Since the reason for which the tank is to be cleaned will dictate the extent of cleaning, this reason must be definitely established. Cleaning may be required for any one or any combination of the following reasons:

1. Routine or periodic cleaning.
2. Reduction in contamination of fuel issued from tank.
3. Inspection of tank condition.
4. Removal of sludge or sediment to gain storage capacity.
5. Change of product.
6. Repairs, replacements, or modifications involving hot work.
7. Location of leaks in tank.
8. Application of lining.

Another step in planning is to ascertain the condition of the tank to be cleaned. This is necessary to determine appropriate methods, procedures, and safety precautions that will apply. Items that should be covered in determining tank condition include:

1. The length of time the tank has been in service.
2. The products that were stored in the tank in the past and the length of time each was stored.
3. The last time cleaning was accomplished and the extent of the cleaning.
4. The product now stored in the tank and, if nonvolatile by name, whether abnormal vapor concentrations exist (contamination with a volatile fuel may have occurred—in any event, a preliminary vapor check should be conducted).
5. The last time repairs were made and the nature of the repairs.
6. The physical condition of the tank itself.
7. The amount of product and sediment in the tank.
8. The amount of contaminated product, if any, that is being issued from the tank.

It is of particular importance to determine if the tank has ever contained leaded gasoline; and if so, whether the tank has been thoroughly cleaned since that time. It is emphasized that (1) an unlined concrete tank which stored leaded gasoline, or (2) a lined concrete tank which stored leaded gasoline while the lining deteriorated, cannot be considered safe from the tetraethyl lead hazard until all fuel impregnated concrete has been removed by such means as sandblasting, or until the concrete has been covered with at least one coat of lining.

To properly plan a tank cleaning project, conditions at the site must be known. The site should be checked for the availability of water, compressed air, electric power, and steam. Water and electric power are almost always required; the other utilities may be required. Temporary lines may have to be installed to provide the necessary service.

Arrangements must be made for toilet facilities and, in case of leaded gasoline tanks, showers for bathing also must be available.

The site should be checked for warning signs that are commensurate with the hazards involved. An estimate must be made of potentially dangerous areas. Signs, as necessary, must be placed at accesses to the hazardous areas. Figure 14-9 shows a warning sign at an aviation fuel storage tank farm.

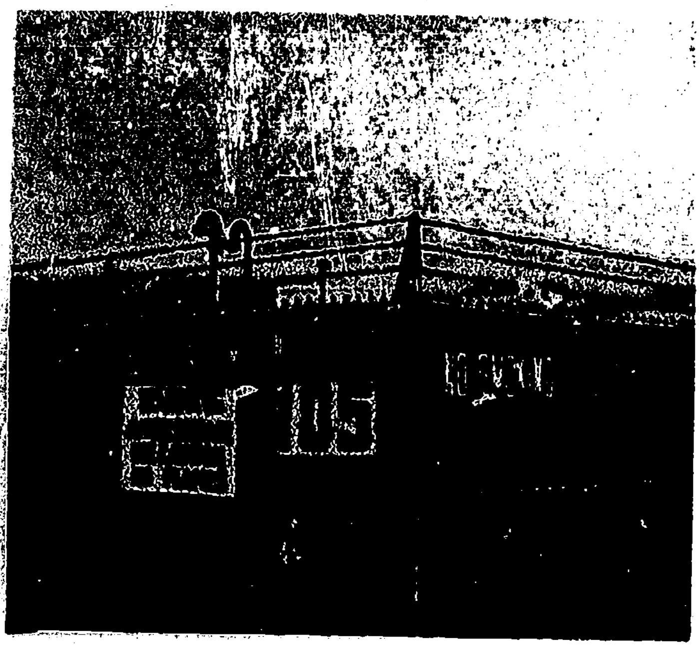

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Figure 14-9. —Warning sign at aviation fuel storage tank farm.

A location for sludge disposal will have to be selected. Sludge and sediment from a tank which contained nonleaded fuels may be buried near the site or elsewhere, or it may be hauled to a burn pit or some other waste disposal area. It must be remembered that the safest known method for disposal of lead-contaminated sludge is by burial in an area where access is controlled and where there is little chance of accidental uncovering. Usually, the most convenient location for burial of sludge is near the tank being cleaned. When there is insufficient area to dispose of lead-contaminated sludge by burial, disposal instructions should be obtained from the Naval Facilities Engineering Command.

Other factors to consider in planning a tank cleaning project include such items as method of vapor-freeing, method of cleaning, extent of cleaning, and assuring that tank cleaning personnel know the hazards and appropriate precautions involved.

PREPARATION FOR CLEANING

Prior to commencing actual cleaning operations, there are several preparatory measures necessary. One such measure involves removal of fuel from the tank to be cleaned. All fuel possible must be pumped or drained from the tank, through existing connections. If possible and feasible, residual fuel in low spots in the tank should then be floated with water and removed. Throughout procedures in removing fuel, sources of ignition should be excluded from the area if flammable vapors are present.

After removal of all fuel possible from the tank, jumpers should be installed around pipeline disconnection points if flammable vapor-air mixtures are likely to exist and if there is no insulating flange at that point. All pipelines must then be disconnected and blinded.

Depending upon the method to be used for vapor-freeing, appropriate manhole covers are to be removed and vapor-freeing equipment placed accordingly. Safety precautions, in accordance with the hazards that exist, must be observed during this operation.

If a pit is to be used for sludge disposal, an appropriate time to dig the pit is during the initial stages of vapor-freeing operations. The quantity of sludge, sediment, and liquid to be removed from the tank must be estimated to determine the size of the pit. The pit must be large enough to hold all sludge and permit covering with a minimum of 12 inches of dirt. A double pit is recommended, with the first pit (receiving pit) being large enough to hold all the sediment, and the second pit (liquid overflow pit) being large enough to hold all the liquid.

VAPOR-FREEING THE TANK

Vapor-freeing a tank not only reduces the fire or explosion hazard, but the health hazard as well. Therefore, all tanks should be vapor-freed to the maximum extent possible and feasible prior to entry of personnel. In conjunction with vapor-freeing, it may be necessary to remove the bulk of vapor-bearing materials.

There are several methods by which a tank can be vapor-freed. The selection of the method employed, however, depends upon various factors, such as time involved, hazards involved, effectiveness of the method, and availability of equipment. What may be appropriate for one tank may not be appropriate for another tank; therefore, good judgment in selecting the method for vapor-freeing is of prime importance.

Use of Steam

When provided in sufficient quantities, steam will displace fuel vapors, evaporate volatile residue, and reduce the viscosity of fuel in impregnated concrete surfaces so that the fuel "bleeds" out; further, it may dilute rich mixtures to such an extent as to render them noncombustible. Steam may be advisable for use in small tanks which have stored heavy fuel oils; it must be remembered, however, that use of steam under certain conditions may introduce a hazard from static electricity sparks.

QUANTITIES AND TEMPERATURES REQUIRED. — In order to use steam effectively, the steam must be supplied in sufficient quantities to heat the interior surface of the tank shell and roof to a minimum of 170° F within a few hours. Otherwise, a point of equilibrium will be established whereby the steam will condense on the walls and roof as fast as it enters, and no further displacement of fuel vapor will be effected. Under such conditions, there is a chance that the vapor-air mixture will be, and will remain in, a flammable condition. On large tanks, it is unlikely that a sufficient supply of steam will be available to accomplish the desired end. The time involved for vapor-freeing by this method is relatively long as compared to mechanical ventilation.

OPENING OF MANHOLES. — Whenever steam is used for vapor-freeing, or as an aid to natural ventilation, the roof openings of the tank must be open to avoid the possibility of (1) excessive pressure resulting from admission of steam or (2) vacuum resulting from tank cooling after the steam flow into the tank has been terminated.

STEAMING. — Steam admitted to a tank will warm the shell surfaces and assist in vaporizing residual volatile fuel, but it will have little effect on thick layers of sludge in the tank bottom because of the low rate of heat transfer. The time involved for steaming may vary from 6 to 12 hours, depending upon the size of tank and the product which was stored in the tank.

VENTILATION. — After steaming, the tank should be ventilated. Mechanical ventilation is recommended.

AIR SAMPLING. — After ventilation, the tank atmosphere should be tested for flammable vapors. If these tests do not indicate safe conditions, ventilation should be continued. If lead hazards exist, personnel must be fully protected upon entry.

LINING DETERIORATION. — Steam will deteriorate organic linings; therefore, it should not be used in lined concrete or steel tanks unless the entire lining is to be removed.

Natural Ventilation

The NATURAL VENTILATION method of vapor-freeing can be used effectively on surface tanks, even though it usually takes a considerable length of time. The roof and shell manholes of the tank are removed, and natural ventilation takes place, with fresh air dispelling the fuel vapors. The length of time required to vapor-free a tank depends to a great extent upon wind and the thermal effect of the sunshine.

In the initial stages of vapor-freeing a surface tank by this method, the fuel vapors, which are heavier than air, will commence to flow out through the bottom shell manholes, with fresh air entering the top. (This may result in high concentration of flammable vapor at ground level, thus creating a hazardous condition.) Within a short period of time, however, the process will be reversed — a chimney effect will be established, with fresh air entering at the bottom manhole openings and fuel vapors dispelling at the top manhole openings. The thermal effect of sunshine increases the flow of air through the tank, thus expediting the vapor-freeing process. Also, the wind will expedite vapor-freeing.

AIDS TO NATURAL VENTILATION. — The placing of a windsail at an open manhole or introduction of steam at bottom manholes will expedite ventilation. The introduction of steam in this instance merely promotes faster circulation and heats the tank and fuel vapors so that a chimney effect is established; the steam itself has little effect on actual displacement of vapors or the reduction of vapor concentration in the tank.

EFFECTIVENESS. — It is evident that vapor-freeing by natural ventilation cannot be effectively used on underground tanks, since this method depends primarily upon fresh air entering at the bottom and vapors leaving at the top. It is possible, however, to have some degree of success when there is wind, by opening two manholes on top of the tank and placing a windsail over one of them. This forces fresh air into the tank at the manhole where the windsail is located, which in turn forces vapors out the other manhole.

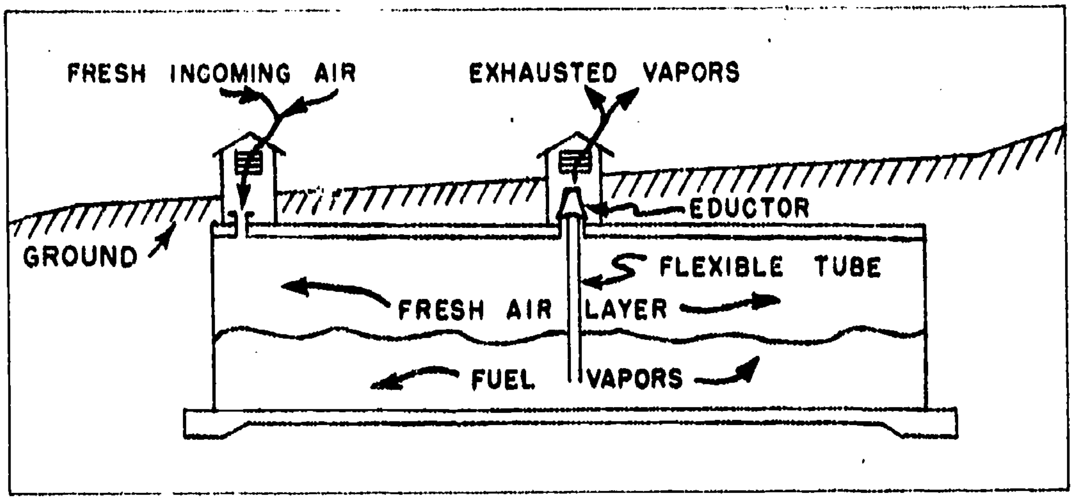

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Figure 14-10. — Vapor-freeing underground tank by use of eductor and flexible tube.

Mechanical Ventilation

MECHANICAL VENTILATION may be accomplished by several methods, any of which, if properly used, will rapidly vapor-free a tank with a minimum of hazard involved. It may be used effectively on both underground and surface tanks, and is advised for use in all tank cleaning projects. If used, mechanical ventilation should be continued for as long as personnel are in the tank. When mechanical ventilation is used, care must be exercised to assure that the dispelled vapors do not re-enter the tank.

EDUCTOR. — This method involves operating one or more air movers of the eductor type that have been placed over roof openings. If already piped to the vicinity of the tank, steam or compressed air may be used to act as an injector (or ejector) for operation of the eductor. Where steam or compressed air is not piped to the area, a portable air compressor may be used, provided it is located in an area not subject to the accumulation of flammable vapors.

In vapor-freeing surface tanks by this method, the eductor is placed over a roof opening, so that vapors may be exhausted into the atmosphere above the tank. Shell manholes are opened to allow entry of fresh air. In vapor-freeing underground tanks, manhole covers are removed and the eductor is placed over one of the openings. For underground tanks, a flexible tube may be placed from the eductor to near the bottom of the tank, so that the fuel vapors may be withdrawn. The flexible tube may be used for surface tanks also, if the shell manholes are closed and other openings are made in the roof for fresh air entry. The practice of using a flexible tube permits withdrawal of the fuel vapors with a minimum of mixing with air, thereby reducing the amount of flammable vapor-air mixtures that may be in the tank — the vapors remain more or less stratified until exhausted, with the fresh air blanketing the vapors by occupying all the space above them. (See fig. 14-10.)

Vapor-freeing by use of eductors is particularly recommended because of simplicity of operation, relative freedom from fire hazards, large volumes of air moved in short periods of time, and greater dissipation of vapors into the air above the tank.

FANS OR BLOWERS. — A fan or blower may be used to blow fresh air into the tank through an opening, which in turn pushes vapors out of the tank through one or more openings; or the fan or blower can be used as an exhauster, in which case the fresh air is pulled into the tank through open manholes and vapors are exhausted at the manhole where the fan or blower is operating. The fan or blower may be placed directly over the open manhole, or it may be located some distance from the manhole and the air conducted to or from the tank by means of a canvas duct or other type of flexible duct. Fans or blowers may be used effectively on either surface or underground tanks, although they are not considered as effective as using the eductor, particularly where large underground tanks are concerned.

Motive power for the fans or blowers may be furnished by compressed air, steam, electric motors, or gasoline driven engines. If electric motors are used, they should be explosion proof if located in areas subject to accumulation of fuel vapors. Gasoline driven engines or air compressors, if used, should be placed in areas not subject to the accumulation of flammable vapors.

EDUCTOR-AND-FOG NOZZLES. — This method, developed by a commercial oil company, employs the use of an eductor and flexible tube in the same manner as previously described. In addition, water fog nozzles are placed on the underside of roof openings where fresh air is admitted to the tank. Use of the fog nozzles decreases the fire or explosion hazard from flammable vapor-air mixtures that might be present.

Water Displacement

Filling the tank with water to displace fuel vapors will initially vapor-free it. However, this method will not prevent additional vapor from being evolved from sludge after the water is removed. The atmosphere may again be unfit to breathe, and may even be within the flammable range. Only under special circumstances would this method be recommended. Further, it may not be practicable due to the large quantities of water usually required and time involved to fill, and then drain, the tank.

CLEANING THE TANK

The extent of cleaning a tank depends upon the reason for cleaning. This, along with the type of fuel which was, or is to be stored, available facilities, and tank construction, will dictate the method used.

The accepted methods of cleaning tanks include cleaning by use of steam; cleaning through use of chemical compounds, solvents, or wetting agents; cleaning by use of systems similar to the Butterworth System; and cleaning by use of high-pressure water. Depending upon the degree of cleanliness desired, scrubbing, scraping, wire-brushing, and sandblasting or shotblasting may be used in conjunction with any of these methods. Regardless of which method is used, adequate safety precautions consistent with the conditions should be observed.

Cleaning of tanks that have not been vapor-freed may be warranted at activities where (1) facilities for cleaning are not sufficiently available, (2) where small tanks are involved, (3) where cleaning may require only the removal of a small amount of sludge or other sediment from the bottom of the tank, or (4) where for other reasons it is impracticable to vapor-free the tank. Any of the applicable methods described in the following paragraphs may be used, but only if adequate precautions are taken to prevent fire or explosion and/or injury to personnel.

Cleaning Methods and Procedures

The following methods and procedures described refer to the basic process only. Further operations, such as scrubbing, scraping, flushing and cleanup operations, are described later.

CLEANING WITHOUT PERSONNEL ENTRY INTO TANKS. — For small tanks, and where cleaning involves only the removal of a small amount of sediment, it may be more practicable to clean the tanks without entry of personnel. This may be accomplished by directing a stream of water through an open manhole while pumping or draining the liquid and sediment from the tank. This method may be particularly adaptable to small underground concrete tanks which are lined.

STEAM CLEANING. — This method may be of value in cleaning tanks under certain conditions; namely, when it is necessary to reduce the amount of fuel impregnated in the concrete of concrete tanks. Unless the entire lining is to be replaced, it should NOT be used in tanks having been coated with organic linings.

Steam jets may be usefully employed to dislodge heavy deposits of sludge in the bottom of the tank. Due to the static electricity hazard, however, steam jets should never be used in tanks if vapor concentrations exceed 50 percent of the lower flammable limit.

The initial phase of steam cleaning, the purpose of which is to warm tank walls, is accomplished through general admission of steam into the tank. This process is the same as that for vapor-freeing by the use of steam.

As much as possible of the sludge and sediment still adhering to the inside surfaces of the tank after steam vapor-freeing must be removed by HOSING DOWN the surfaces with water. Removal of water and sediment during this operation may be effected by draining (if applicable), by use of the tank sump pump, or by use of a portable pump. Ventilation should be provided throughout this operation. Protective equipment should be worn by personnel in the tank, if tests for flammable vapors indicate unsafe conditions. If the tank has contained leaded gasoline, protective equipment should be worn, regardless of ventilation or vapor concentrations.

If, after hosing down, it is apparent that the tank has not been satisfactorily cleaned, steam should again be introduced into the tank. Ventilation should then be resumed until satisfactory air conditions are again retained. The tank must then receive an additional hosing down.

CLEANING WITH CHEMICAL COMPOUNDS, SOLVENTS, AND WETTING AGENTS. — Solvents, compounds, detergents, or wetting agents may be used to expedite cleaning, to extract fuel from porous surfaces, or to help loosen scale from steel surfaces. All must be used in strict accordance with manufacturer's instructions. It is pointed out that these substances will not remove the TEL hazard — entry of personnel into the tank for final cleanup operations is necessary.

Carbon tetrachloride must NOT be used. It is highly toxic, and may gain access into the body through inhalation of its vapors or by absorption of the material through the skin.

Mild detergents or wetting agents, only, may be used on organic linings. Other compounds or solvents may deteriorate the lining.

Cleaning compounds, wetting agents, or detergents may be mixed with water for hosing down operations, or they may be used in conjunction with scrubbing operations involving the use of buckets and brooms.

Certain chemical compounds, when added to a tank full of water, will be effective in cleaning operations. In this instance, hot water is generally required.

CLEANING WITH BUTTERWORTH AND SIMILAR SYSTEMS. — These systems were developed primarily for shipboard use. However, they have been, and may be used to clean shore-based steel tanks. An example of their use would be to clean black product storage tanks for the storage of white product. BLACK PRODUCT refers to burner fuel oils, and WHITE PRODUCT refers to diesel oils and lighter products.

The Butterworth System employs the use of rotating nozzles, hot water, and, as necessary, caustic compounds. Due to equipment and compounds required, and due to the many variable items and conditions to be considered, use of such systems for cleaning shore tanks is not normally employed. If it is planned to use such a system, guidance from the Naval Facilities Engineering Command should be obtained.

CLEANING WITH HIGH-PRESSURE WATER STREAM. — This method is probably the most simple, and it is the one most commonly used. It involves directing the high-pressure water, through a hose, against all surfaces to be cleaned. The pressure and action of the water will, in most instances, wash away the sludge on the surface and loosen and knock off adherent scale. On steel surface tanks, hitting the shell of the tank with a heavy object will assist in loosening the scale and causing it to drop off. Also, scrubbing the surface with a broom will assist in removing sludge and scale.

Extent of Cleaning

As previously pointed out, the thoroughness or extent of cleaning will depend upon the purpose for which the tank is being cleaned.

NORMAL OR ROUTINE CLEANING. — The extent of cleaning described hereunder for normal or routine cleaning may be considered to include cleanings required for the purpose of locating leaks, sludge removal, inspection, reducing the amount of contaminated product being issued from the tank, and most repairs involving cold work. In some instances, normal cleaning will be satisfactory for a change in product, such as from white product to black.

For STEEL TANKS, the interior of the tank shell and bottom, columns, channels, and all interior accessory equipment such as pumps, piping, and ladders should be cleaned until free of all dirt, scale, loose particles, fuel sludge, and other deleterious particles. The tank roof and roof beams should be cleaned until free of all loose and loosely adherent material.

With the possible exception of steam cleaning and cleaning by use of high-pressure water, any of the previously described methods will usually clean a tank to the extent desired without scraping. Scrubbing with brooms will probably be necessary for areas other than the roof and roof beams. Occasional scraping may be required to free adherent scale. Wire-brushing usually will not be required unless steel surfaces are extremely pitted. In the case of steam cleaning and high-pressure water cleaning, scrubbing and scraping of the tank floor will probably be necessary. The scrubbing and/or scraping that may be required with steam cleaning should be accomplished during or following the washing operation or, if applicable, after the additional steaming.

For CONCRETE AND STEEL TANKS WITH ORGANIC LININGS, the interior of the tank shell and bottom, columns, and other items that have an organic coating should be cleaned until free of all dirt, loose particles, fuel, sludge, and other deleterious particles. All interior uncoated steel surfaces, such as pumps, piping, and ladders, should be cleaned to the same extent previously described for steel tanks. The tank roof and roof beams should be cleaned until free of all loose and loosely adherent material.

The only acceptable method for cleaning the lined surfaces is by use of high-pressure water hose, or by manual washing with water, either of which may be accompanied by scrubbing with brooms or cloth. Either cold or warm water may be used. Mild detergents or wetting agents also may be used. As lined surfaces are relatively easy to clean, no further cleaning procedures should be necessary. As with cleaning steel tanks, cleaning of uncoated metal surfaces may require scrubbing with brooms, wire-brushing, and/or occasional scraping.

CONCRETE TANKS should be cleaned in the same manner, and to the same extent, as steel tanks. Caution must be exercised, however, in cleaning concrete tanks with steam or hot water — high temperatures may cause structural damage. Concrete other than just its surface should never be heated to above 130° F.

CLEANING FOR REPAIRS. — The extent of cleaning required under normal or routine cleaning will be satisfactory for most types of repairs involving cold work, except application of lining. Where hot work or lining application is involved, the extent of cleaning must be to a greater degree than for normal cleaning.

For STEEL TANKS, metal surfaces in the area of hot work are to be cleaned to bare (sometimes referred to as "bright") metal. This cleaning will probably entail the use of sandblasting or shotblasting equipment. Wire-brushing or use of solvents, in some instances where only a small area is concerned, may prove satisfactory. For application or repair of organic linings, the surfaces involved must be cleaned to bare metal.

Sludge and Sediment Removal

Sludge and sediment removal is to be accomplished during or following other cleaning operations. To facilitate sludge and sediment removal and to facilitate cleaning operations in general, it may be advisable, or even necessary, for certain repair operations, to cut a large opening in the shell of a surface tank for use as a doorway.

REMOVAL BY BUCKETS. — Possibly the simplest way to remove sludge and sediment from a tank is to sweep or wash it into piles, shovel it into buckets, and remove the buckets through an open manhole. The sludge may then be hand-carried to a sludge pit or to a truck for further transporting to a disposal area; or it may be transferred to wheelbarrows for further transporting to the sludge pit or truck. To minimize the possibility of spilling, buckets used in sludge removal should NOT be filled more than three-quarters full.

REMOVAL BY PUMP. — Before disconnecting sump pump piping (if applicable), removal of water, sludge, and sediment may be effected through use of sump pumps. The bulk of material, however, is most effectively removed through use of steam operated ejectors, or through use of pumps of the self-priming type, sometimes referred to as diaphragm pumps, sludge pumps, or vacuum pumps. With use of these types of pumps, the sludge, sediment, and water can be pumped directly from the floor of the tank, through a hose, to a sludge pit or into a tank truck for further transporting to the disposal area.

SLUDGE AND SEDIMENT FROM LEADED GASOLINE TANKS. — It must be remembered that for tanks having contained leaded gasoline, all sludge, rust, and other sediment are potentially dangerous. THESE MATERIALS MUST BE KEPT WET AT ALL TIMES UNTIL DISPOSED OF. If they are spilled on the ground outside the tank, they must be removed and disposed of in the proper manner. Blasting materials that have been used in leaded gasoline tanks should be considered to contain lead products; therefore, they should be handled and disposed of in the same manner as lead-contaminated sludge.

Tank Rinsing

Following the removal of substantially all sludge and sediment from the tank, the tank floor should be swept down to remove remaining sediment. The entire tank should then be rinsed or flushed with clear water, regardless of the method used for cleaning. Rinsing through use of a water hose is recommended. To reduce the possibility of product contamination, thorough rinsing cannot be overemphasized when chemical compounds, caustic solutions, solvents and detergents have been used.

Tank Drying

After the tank has been rinsed and all water removed, the remaining water on the tank floor, in channels or other pockets, should be removed by using squeegees or mops, by wiping with rags, or by using a Navy-approved absorbent compound.

CAUTION: Sawdust should NOT be used to soak up oils and other flammables unless treated with a fire retardant.

If the tank contained leaded gasoline, all absorbent materials used should be treated as lead-contaminated materials; they should be removed from the tank and disposed of along with the sludge.

After absorbent materials are used to wipe the surfaces, the tank should be ventilated until dry. Mechanical ventilation will expedite drying, and will probably be required to dry underground tanks. Upon drying, the tank is ready for inspection.

CLEANUP, INSPECTION, AND ACCEPTANCE

After the tank has been cleaned, inspected, and accepted as being clean to the extent specified, there are certain other operations necessary before the entire tank cleaning project can be considered completed. Several operations, which often are required, are described briefly below.

The sludge pit—if one has been used—must be filled. The top 12 inches or more of the fill should be clean dirt. The depth of dirt placed over the pit should be sufficient to ensure a level surface after settlement.

87.52

Figure 14-11.—Warning sign for buried sludge.

When lead-contaminated sludge is involved, the location of the buried sludge should be conspicuously posted with a wood or metal sign. (See fig. 4-11.) The sign should be dated and should read as follows:

DANGER
Materials Containing Tetraethyl Lead
Buried Here
DO NOT UNCOVER

All valves, piping, manhole covers, and other items removed at the start of the job must be replaced, using new gasket material, as applicable. All equipment and materials used for the cleaning operations should be removed from the site, and the site should be restored to its original condition.

A tank history card for each tank should be maintained at the activity level. All pertinent information regarding cleaning, repair, and product storage should be entered on this tank history card.

CHAPTER 15

BOILERS

A BOILER is an enclosed vessel in which water is converted to steam by the burning of fuel and raised to the proper temperature and pressure necessary to serve its intended purpose.

A central heating plant may have one or more boilers which utilize gas, oil, or coal as fuel. The steam generated is used to heat buildings and to provide hot water and steam for cleaning, sterilizing, cooking, and laundering operations. Small heating boilers also provide steam and hot water for small buildings.

A careful study of this chapter will help you acquire a useful knowledge of steam generation, types of boilers pertinent to SEABEE operations, various fittings commonly found on boilers, and so on. A main objective of this instruction is to help you lay the foundation on which to develop skill in the operation, maintenance or repair of boilers.

STEAM GENERATION THEORY

To acquaint you with some of the fundamentals underlying the process of steam operation, suppose that you set an open pan of water on the stove and turn on the heat. You will find that the heat causes the temperature of the water to increase and, at the same time, to expand in volume. When the temperature reaches the BOILING POINT (212° F, or 100° C, at sea level) a physical change occurs in the water; the water starts vaporizing. If you hold the temperature at boiling point long enough, the water will continue to vaporize until the pan is dry. Now a point to remember is: THE TEMPERATURE OF WATER WILL NOT INCREASE BEYOND THE BOILING POINT. Even if you add more heat after the water starts to boil, the water will not get any hotter, as long as it remains at the same pressure.

But suppose you place a close-fitting lid on the pan of boiling water. The lid prevents the steam escaping from the pan, and this results in a buildup of pressure inside the container. However, if an opening is made in the lid, steam will escape at the same rate it is generated. As long as any water remains in the vessel, and as long as the pressure remains constant, the temperature of the water and steam will remain constant and equal.

The steam boiler operates on the same basic principle as a closed container of boiling water. By way of comparison, it is true with the boiler as with the closed container, that steam formed in boiling tends to push against the water and sides of the vessel. Because of this downward pressure in the surface of the water, a temperature IN EXCESS of 212° F is required for boiling. The higher temperature is obtained simply by increasing the supply of heat. Bear in mind, therefore, that: AN INCREASE IN PRESSURE MEANS AN INCREASE IN BOILING POINT TEMPERATURE.

There are a number of technical terms used in connection with steam generation. Here are some of the commonly used terms you should know.

DEGREE is defined as a measure of heat intensity. TEMPERATURE may be defined as a measure in degrees of sensible heat. The term SENSIBLE HEAT refers to heat that can be measured with a thermometer.

Technically speaking, HEAT is a form of energy which is measured in units known as British thermal units (Btu's). One Btu is the amount of heat required to raise 1 pound of water 1° Fahrenheit at sea level.

Simply stated, the term STEAM means water in a vapor phase. DRY SATURATED STEAM is steam at the saturation temperature corresponding to pressure, and containing no water in suspension. WET SATURATED STEAM is steam at saturation temperature corresponding to pressure, and containing water particles in suspension.

The QUALITY of steam is expressed in terms of percent. For instance, if a quantity of wet steam consists of 90 percent steam and 10 percent moisture, the quality of the mixture is 90 percent.

You know, of course, that all the water in a vessel, if held at boiling point long enough, will change into steam. What you may not know, is that there is a definite relationship between the pressure and temperature. AS LONG AS THE PRESSURE IS HELD CONSTANT, THE TEMPERATURE OF THE STEAM AND BOILING WATER WILL REMAIN THE SAME.

SUPERHEATED STEAM is steam at a temperature higher than saturation temperature corresponding to pressure. For example, a boiler may operate at 415 psig (pounds per square inch, gage). The corresponding saturation temperature for this pressure is 445° F and this will be the temperature of the water in the boiler and the steam in the drum. (Charts and graphs are available for use in computing this pressure-temperature relationship.) This steam can be passed through a superheater where the pressure will remain about the same but the temperature will be increased to some higher figure.

BOILER DESIGN REQUIREMENTS

It is essential that a boiler meet certain requirements before it is considered satisfactory for operation. Three important requirements are that the boiler (1) be safe to operate; (2) be able to generate steam at the desired rate and pressure; and (3) be economical to operate.

Make it a point to familiarize yourself with the boiler Code and other requirements applicable to the area in which you are located.

Here are a few rules set up by ASME (American Society of Mechanical Engineers). These show the general guidelines used by engineers when designing boilers you will use.

For economy of operation, and to generate steam at the desired rate and pressure, a boiler must have:

ADEQUATE water and steam capacity
RAPID and positive water circulation
A LARGE steam generating surface
HEATING surfaces which are easy to clean on both water and gas sides
PARTS accessible for inspection
A CORRECT amount and proper arrangement of heating surface
FIRE BOX for efficient combustion of fuel.

TYPES OF BOILERS

In this training manual we are concerned, primarily, with the FIRE-TUBE type of boiler, since it is the type generally used in SEABEE operations. We are interested, secondarily, in the WATER-TUBE type of boiler, which may occasionally be found in use at some activities. Our discussion herein mainly concerns the different designs and construction features of fire-tube boilers.

The basis of identifying the two types is as follows:

WATER-TUBE BOILERS are those in which the products of combustion surround the tubes through which the water flows.

FIRE-TUBE BOILERS are those in which the products of combustion pass through the tubes and the water surrounds them.

FIRE-TUBE BOILERS

The SCOTCH MARINE type of fire-tube boiler is especially suited to SEABEE needs. (See fig. 15-1.) A portable unit, it can be moved with ease and with a minimum of foundation work. As a complete self-contained unit its design includes automatic controls, steel boiler, and burner equipment. These features are a big advantage because no disassembly is required when you have to take the boiler to the field for emergency work, or have to move it to a more suitable location in the area.

The Scotch type boiler has a 2-pass (or more) arrangement of tubes which run horizontally. This allows the heat inside the tubes to travel back and forth. It also has an internally fired furnace, with a cylindrical combustion chamber. There is a flue gas outlet, or smoke breeching, located on the front end of the boiler. Oil is the fuel commonly used to fire the Scotch type boiler. Where desirable, though, it can be fired by gas, coal, or wood.

One advantage that the Scotch type boiler has over the water-tube boiler is that it requires less space, and can be set up in a low-ceiling room. Then, too, its tubes being all the same size saves time and trouble in making tube replacements.

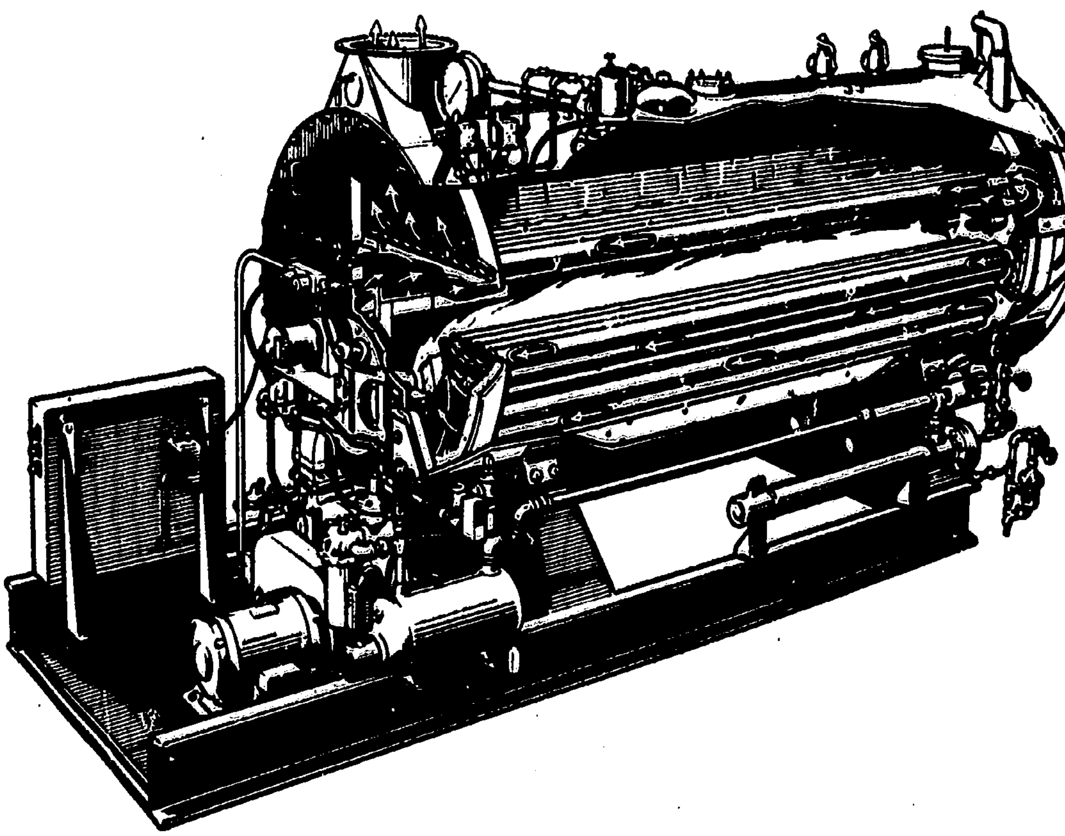
The Scotch type boiler also has a few disadvantages. Its shell runs from 6 to 8 feet in diameter, a detail of construction which makes a large amount of reinforcing necessary. Too, the fixed dimensions of its internal furnace cause some difficulty in cleaning the surfaces of the section below the combustion chamber. Another drawback is encountered in the limited capacity and pressure of the Scotch type boiler.

The SETTING of the Scotch type boiler is self-supporting. The shell rests in two or more steel cradles, and the boiler is sometimes pitched slightly to aid in draining the boiler. The setting includes a blow-down pipe which is connected to the bottom of the shell which, in turn, is screwed into a pad riveted to the shell.

The flow of gases in a 2-pass Scotch type boiler is toward the rear of the combustion chamber, then return by way of the tubes to the front, and out into the smoke box and stack breeching.

An important safety device sometimes used is the fusible plug, which will provide added protection against low water. In case of low water, the plug core melts and steam escapes, and a loud noise results, warning the operator. On the Scotch type boiler, the fusible plug usually is located in the crown sheet, but sometimes it is found in the upper back of the combustion chamber. (Types of fusible plugs will be discussed later in this chapter.)

Accesses for cleaning, inspection, and repair of the boiler watersides are provided through a manhole in the top of the boiler shell, and a handhole in the water leg. The MANHOLE is an opening which is large enough for a man to enter the boiler shell for inspection, cleaning, and repair purposes. On such occasions,



54.114

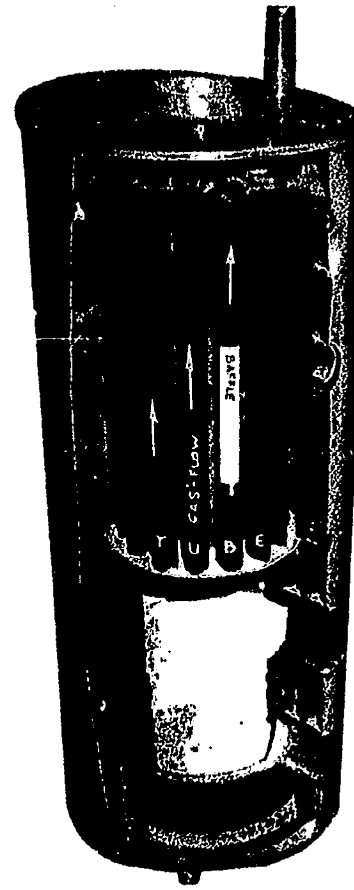
Figure 15-1.—Scotch marine type fire-tube boiler.

always make sure all valves are secured, locked, and tagged, and that the man in-charge knows you are in there. Also, have a man stationed at the outside entrance to aid and assist. The HAND-HOLE is an opening large enough to permit hand entry for cleaning, inspection, and repairs to headers and tubes.

VERTICAL-TUBE BOILER

In some fire-tube boilers, the tubes run vertically, as opposed to the horizontal arrangement of tubes in the Scotch type boiler. The VERTICAL-TUBE boiler sits in an upright position as indicated in figure 15-2. Therefore, the products of combustion (gases) make a single pass, traveling straight up through the tubes and out the stack.

The vertical fire-tube boiler is similar to the horizontal fire-tube boiler in that it is a portable, self-contained unit requiring a minimum of floor space. Handholes are also provided for cleaning and repair purposes. Though self-supporting in its setting (no brickwork or foundation being necessary) it MUST be level. The vertical fire-tube boiler has the disadvantage of a limited capacity and furnace volume as does the horizontal-tube design.



29.218.1
Figure 15-2.—Cutaway view of vertical fire-tube boiler.

A main factor that must be considered before selecting a vertical fire-tube boiler is the amount of overhead space in buildings where it will be used. Since it sits in an upright position, a room with a high ceiling is necessary for its installation.

The blowdown pipe of the vertical fire-tube boiler is attached to the lowest part of the water leg, and the feed-water inlet opens through the top of the shell. The boiler's fusible plug is installed either (1) in the bottom tube sheet or crown sheet, or (2) on the outside row of tubes, one-third the height of the tube from the bottom.

HORIZONTAL RETURN TUBULAR BOILER

In addition to operating portable boilers such as the Scotch marine type and vertical fire-tube boiler, the UT must also be able to operate stationary boilers, both in the plant and in the field. A STATIONARY BOILER can be defined as one having a permanent foundation and not easily moved or relocated. A popular type of stationary fire-tube boiler is the HORIZONTAL RETURN TUBULAR (HRT) boiler, illustrated in figure 15-3.

The initial cost of the HRT boiler is relatively low, and installing it is not too difficult. The boiler setting can be readily changed to meet different fuel requirements—coal, oil, wood, or gas. Tube replacement is also a comparatively easy task since all tubes in the HRT boiler are the same in size, length, and diameter.

The gas flow in the HRT boiler is from the firebox to the rear of the boiler, then return through the tubes to the front where it is discharged to the breeching and stack.

The HRT boiler has a pitch of 1 to 2 inches to the rear. This allows sediment to settle

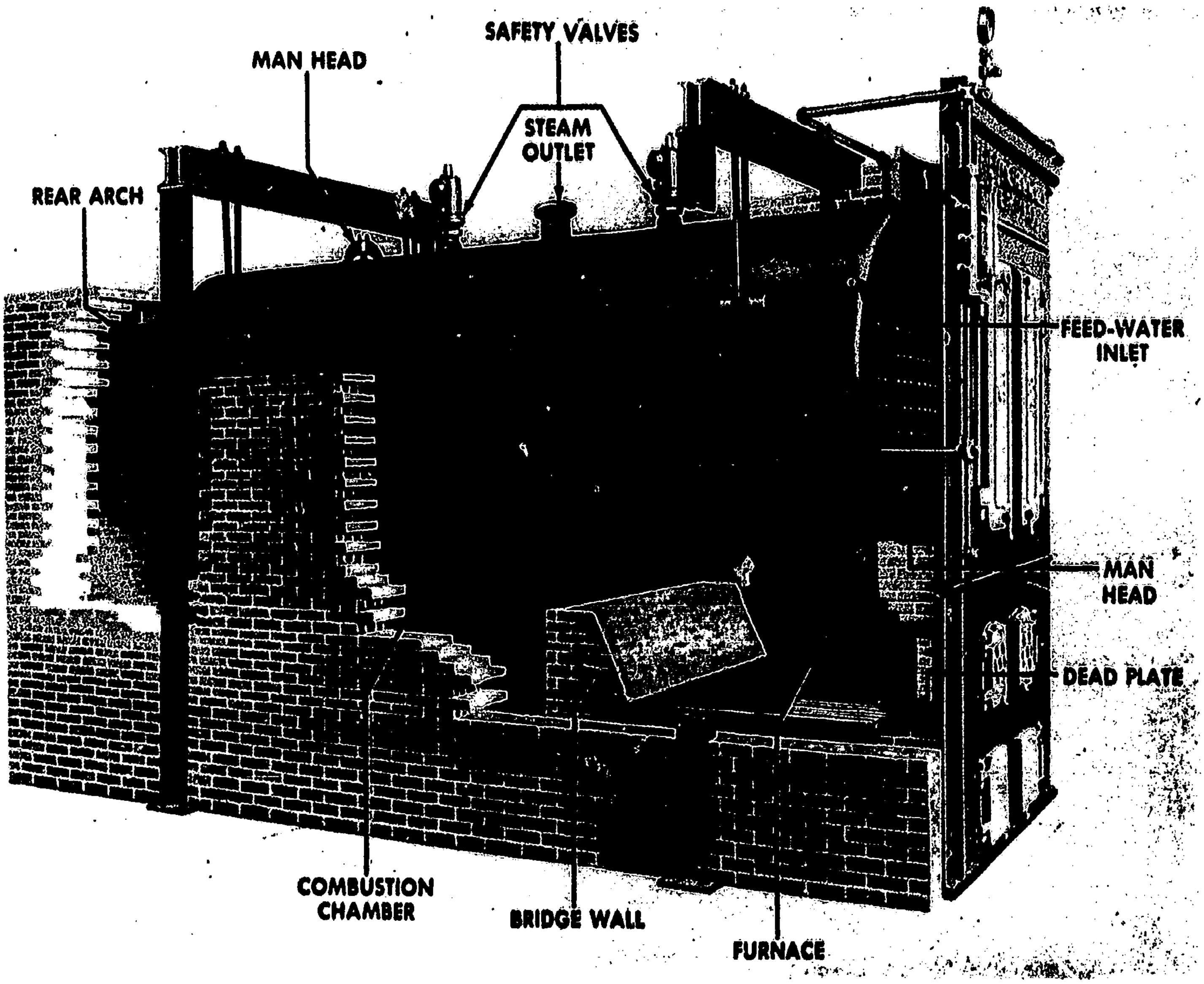


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Figure 15-3. — Horizontal return tubular (HRT) fire-tube boiler.

toward the rear near the bottom blow connection. The fusible plug is located 2 inches above the top row of tubes. Boilers over 40 inches in diameter require a manhole in the upper part of the shell. Those over 48 inches in diameter must have a manhole in the lower, as well as in the upper part of the shell. Don't fail to familiarize yourself with the location of these and other essential parts of the HRT boiler. The knowledge you acquire will be a great help to you, in the performance of duties involving boilers.

FIREBOX BOILER

Another type of fire-tube boiler is the FIREBOX boiler, which generally is used for stationary purposes. A split section of a small firebox boiler is illustrated in figure 15-4. Gases in the firebox boiler make two passes through the tubes. Firebox boilers require no setting except possibly an ash pit (when using coal fuel). As a result, they can be quickly installed and placed in service. Gases travel from the fire box through a group of tubes to a reversing chamber and return through a second set of tubes to the flue connection on the front of the boiler, and are discharged up the stack.

WATER-TUBE BOILERS

Water-tube boilers may be classified in a number of ways. For our purpose, though, let us classify them as straight-tube andbent-tube. These two classes will be discussed separately in succeeding sections. To avoid confusion, make sure you study carefully each illustration referred to throughout the discussion.

Straight Tube

The STRAIGHT-TUBE category of water-tube boilers includes three types: sectional-header cross drum, box-header cross drum, and box-header longitudinal drum.

Figure 15-5 shows a SECTIONAL-HEADER CROSS DRUM boiler with vertical headers. HEADERS are steel boxes into which the tubes are rolled. Feed water enters and passes down through the downcomers (pipes) into the rear sectional headers from which the tubes are supplied. The water is heated and some of it changes into steam as it flows through the tubes to the front headers. The steam-water mixture returns to the steam drum through the circulating tubes and is discharged in front of the steam-drum baffle which helps to separate the water and steam.

Steam is removed from the top of the drum through the dry pipe. This pipe extends along

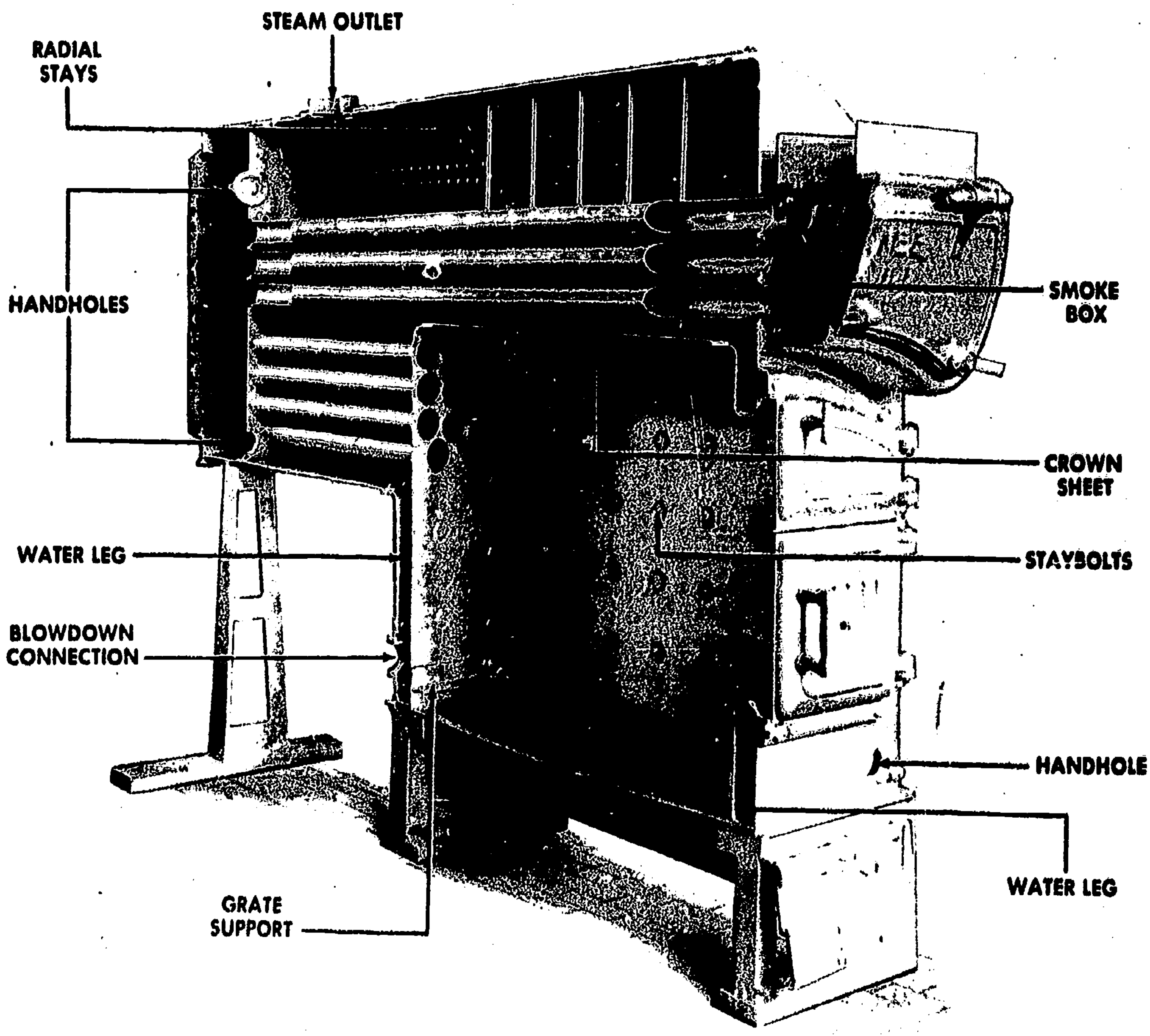

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Figure 15-4.—Split section of small firebox boiler.

the length of the drum, and has holes or slots in the top half for steam to enter.

Headers, the distinguishing feature of this boiler, are usually of forged steel and are connected to the drums with tubes. Headers may be vertical (as in fig. 15-5) or at right angles to the tubes. The tubes are rolled and flared into the header. A handhole is located opposite the ends of each tube; these facilitate inspection and cleaning. A mud drum is connected to the bottom of each rear header by short nipples. Its purpose is to collect sediment, which is removed by blowing down the boiler.

Baffles are usually so arranged that gases are directed across the tubes three times before being discharged from the boiler below the drum.

The BOX-HEADER CROSS DRUM BOILER is illustrated in figure 15-6. Box-headers are shallow boxes made of two plates: a tube-sheet plate, which is bent to form the sides of the box; and a plate containing the handholes, which is riveted to the tube-sheet plate. Some are designed so that the front plate can be removed for access to tubes. Tubes enter at right angles to the box-header and are expanded and flared in the same manner as the sectional-header boiler The boiler is usually built with the drum in front. It is supported by lugs fastened to the box-headers. This boiler has either cross or longitudinal baffling, arranged to divide the boiler into three passes.

Water enters the bottom of the drum, flows through connecting tubes to the box-header, through the tubes to the rear box-header, and back to the drum.

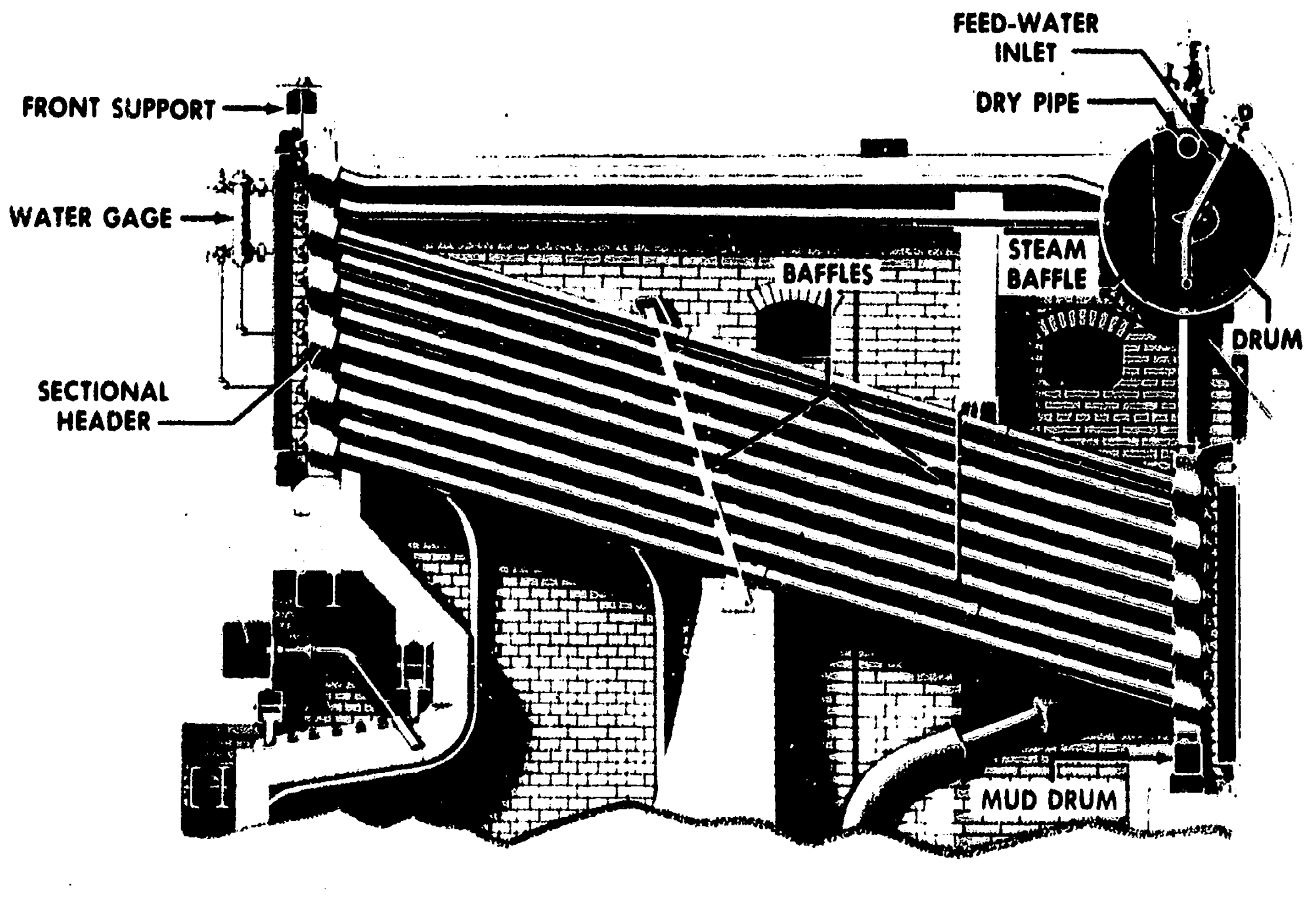

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Figure 15-5. —Sectional-header cross drum boiler (straight water tube).

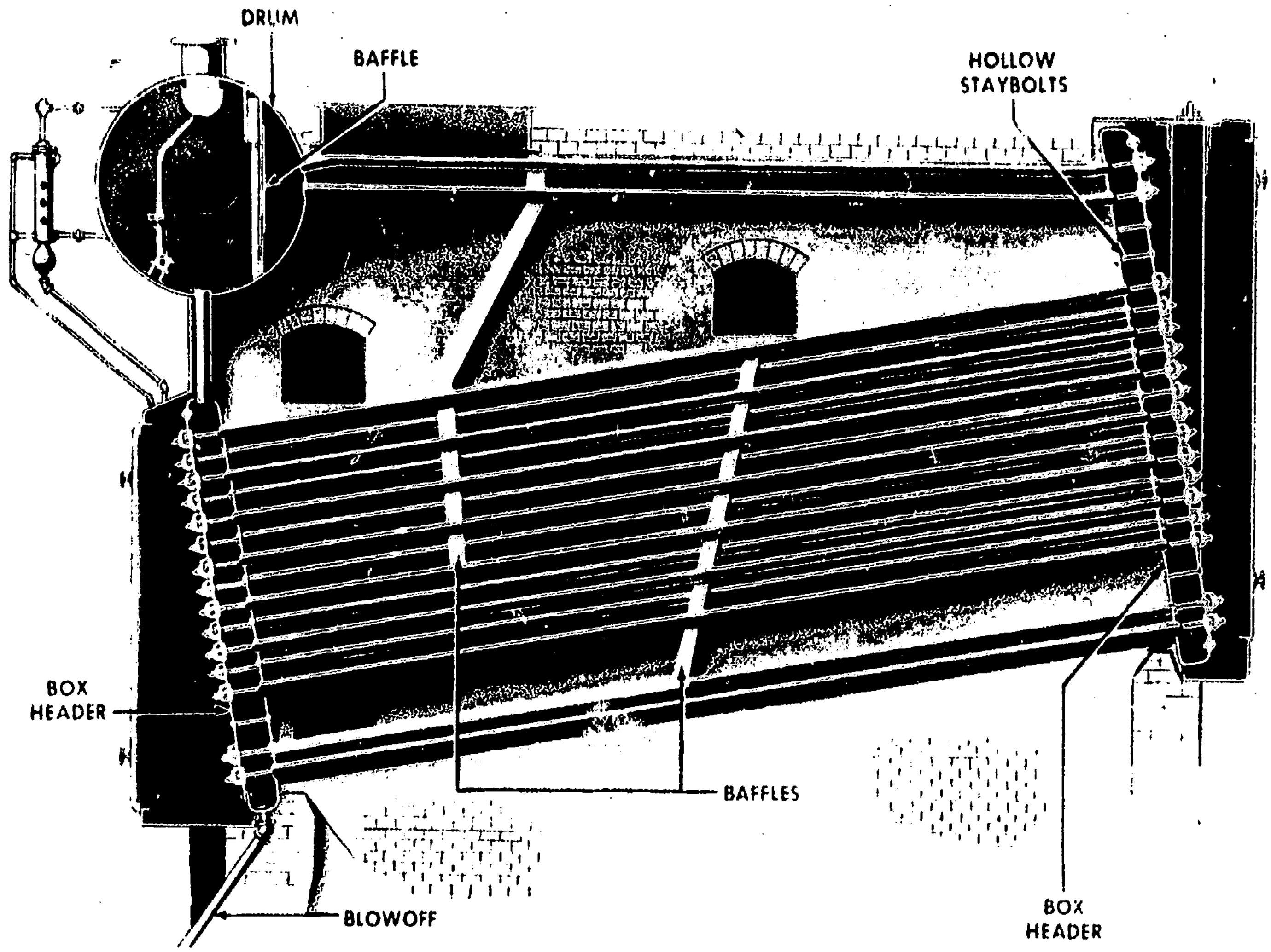

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Figure 15-6. — Box-header cross drum boiler (straight water tube).

BOX-HEADER LONGITUDINAL DRUM BOILERS have either a horizontal or inclined drum. Box-headers are fastened directly to the drum, when the drum is inclined. If the drum is horizontal, the front box-header is connected to it at an angle greater than 90 degrees. The rear box-header is connected to the drum by tubes. Longitudinal or cross baffles can be used with either type.

Bent Tube

Figure 15-7 illustrates one of the many types of bent-tube (water-tube) boilers. Boilers of this type usually have three drums. The drums are usually of the same diameter and positioned at different levels with each other. The uppermost or highest positioned drum is referred to as the STEAM DRUM, while the center positioned drum is referred to as the WATER DRUM, and the lowest, the MUD DRUM. The drums are connected by tube banks. The tubes are bent at the ends to enter the drums radially.

Water enters the top rear drum, passes through the tubes to the bottom drum, and then moves up through the tubes to the top front drum. A mixture of steam and water is discharged into this drum; steam returns to the top rear drum through the upper row of tubes while water travels through tubes in the lower rear drum by tubes extending across the drum, and enters a small collecting header above the front drum.

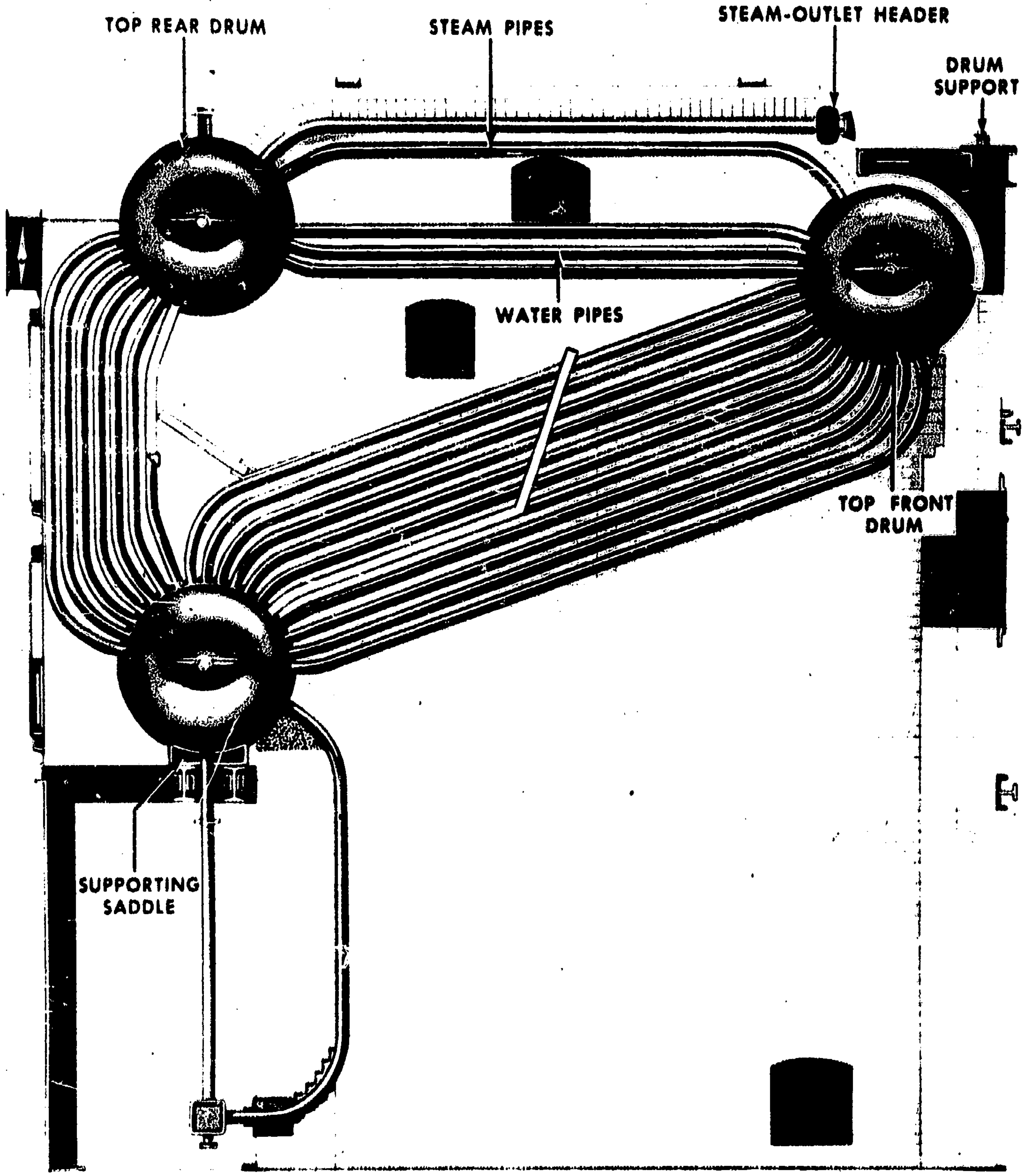

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Figure 15-7. — Bent-tube boiler (water tube).

Many types of baffle arrangement are used with bent-tube boilers. Usually, they are installed so that 70 to 80 percent of the heat will be absorbed by the inclined tubes between the lower drum and the top front drum.

The water-tube boilers discussed above offer a number of worthwhile advantages. For one thing, they afford flexibility in starting up. They also have a high productive capacity, which ranges from 100,000 to 1,000,000 pounds of steam per hour. In case of tube failure, there is little danger of a disastrous explosion of the water-tube boiler. The furnace not only can carry a high overload, but also can be modified easily for firing by oil or coal. Still another advantage is afforded by the minimum difficulty encountered in getting to sections inside the furnace for cleaning and repair purposes.

Now let us look at the other side of the picture which shows several disadvantages common to water-tube boilers. Here it can be pointed out that a high construction cost is involved, a factor which poses one of the main drawbacks to use of water-tube boilers. The large assortment of tubes required of this boiler, and the excessive weight per unit weight of steam generated, are other unfavorable factors.

BOILER PARTS AND FITTINGS

By now you should have a general idea of the overall basic structure of a boiler. A number of questions probably have come to mind as to the importance of certain boiler parts and the operation or function of various devices, such as controls, valves, try-cocks, and the like. That brings us to the topic of PARTS AND FITTINGS. A sufficient number of essential boiler parts and fittings will be discussed to provide a background for further study. As a reminder, and in case you should run across some unit or device not covered in this text, check the manufacturer's manual for information on details of its construction and method of operation (where applicable).

The term FITTINGS includes various controlling devices on the boiler. Bear in mind, therefore, that fittings are vitally important to economy of operation and safety of personnel and equipment. A thorough knowledge of fittings is necessary if you are to acquire skill in the installation, operation, and servicing of steam boilers.

SETTINGS

The SETTING is the structure that encloses the boiler and forms the furnace. It may also support all or part of the boiler. The self-supported type of setting is common. The outer wall is built of hard-burned brick. The inner wall is built of firebrick to withstand high temperatures. Several examples of this type of setting are pictured in figure 15-8.

CHIMNEYS, DRAFT FANS AND BREECHINGS

Chimneys are necessary for discharging the products of combustion at an elevation high enough to comply with health requirements, and to prevent nuisance due to low flying smoke, soot, and ash. A boiler needs draft to mix air correctly with the fuel supply, and to conduct the flue gases through the complete setting.

The air necessary for combustion of fuel cannot be supplied normally by natural draft. Therefore, draft fans may be used to ensure that the air requirements are properly met. Two types of draft fans used on boilers are

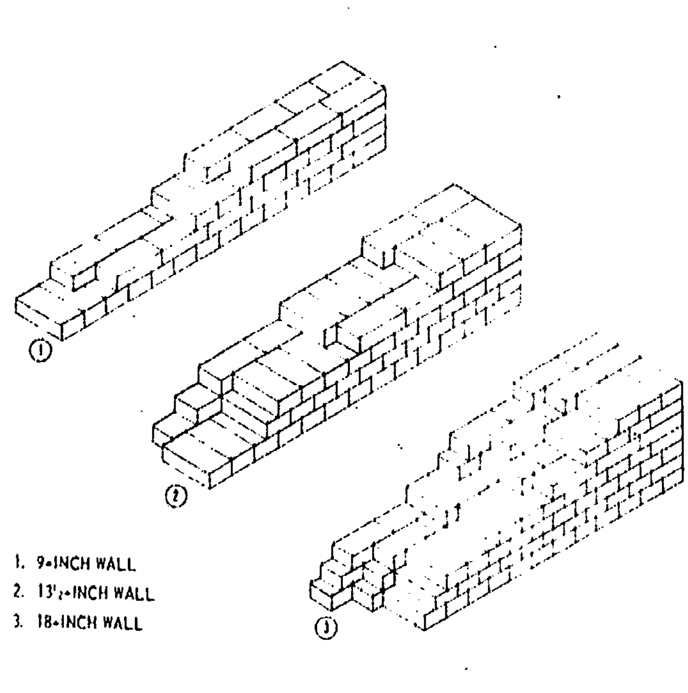

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Figure 15-8. — Furnace sidewall construction.

forced-draft and induced-draft fans. They are damper-controlled and usually are driven by an electric motor.

The FORCED-DRAFT fan forces air through the fuel bed, or fuel oil burner, and into the furnace to supply air for combustion. The INDUCED-DRAFT fan draws gases through the setting, thus facilitating their removal through the stack.

Breechings are used to connect the boiler to the stack. They are usually made of sheet steel, with provision for expansion and construction. The breeching may be carried over the boilers, in back of the setting, or even under the boilerroom floor. Keep breechings as short as possible, and free from sharp bends and abrupt changes in area. The cross-sectional area should be approximately 20 percent greater than that of the stack, to keep draft loss to a minimum. A breeching with circular cross section causes less draft loss than one with rectangular or square cross section.

GAGE GLASSES

Each boiler must have at least one WATER-GAGE GLASS; if the operation pressure is 400

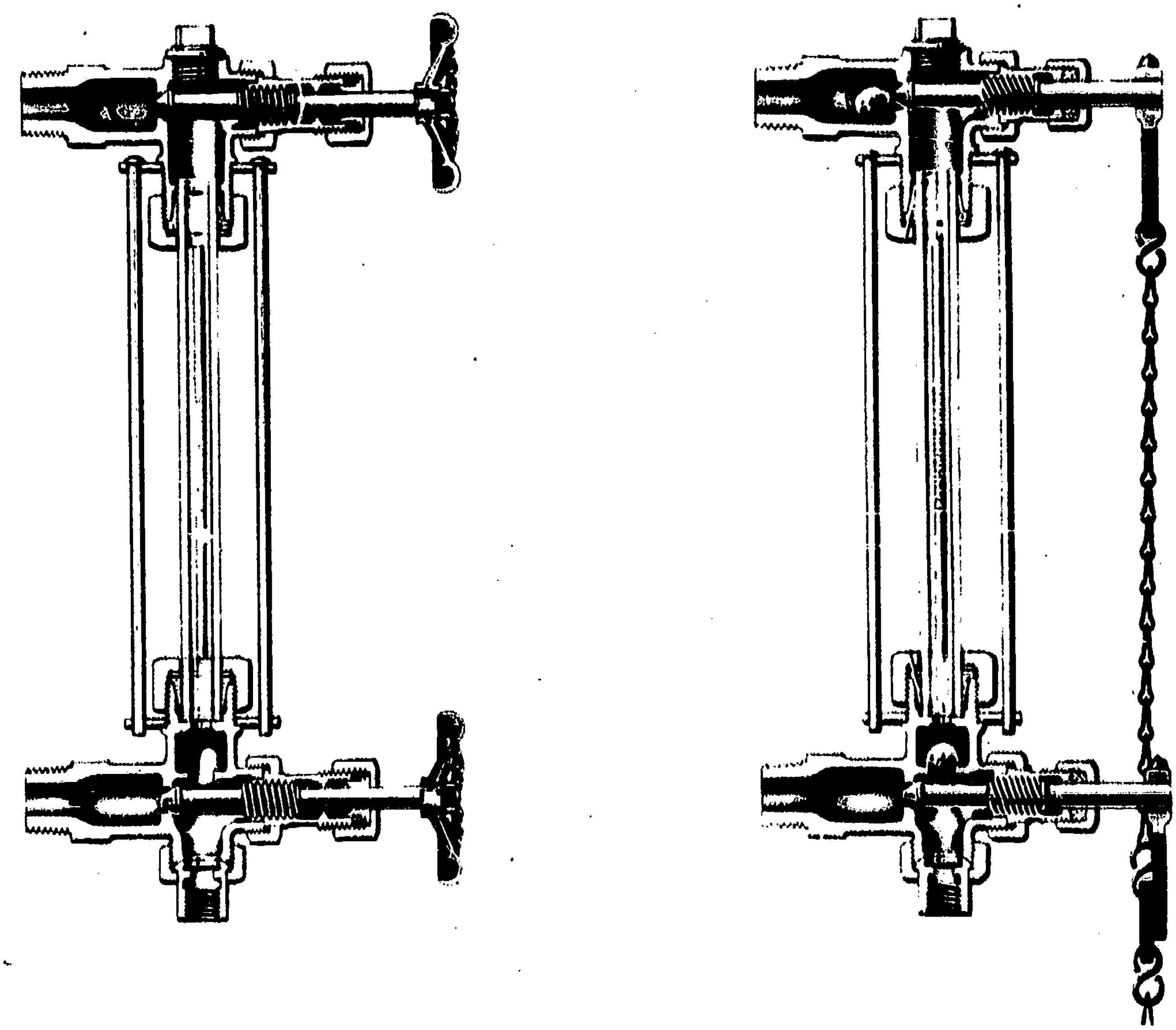

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Figure 15-9. — Typical water-gage glasses.

psi or more, two gage glasses must be provided. The gage glass allows you to tell by sight the water level in the steam drum. Each gage glass must have a valved drain, and the gage glass and pipe connections must not be less than 1/2-inch pipe size. The lowest visible part of the water gage must be at least 2 inches above the lowest permissible water level, which is defined as the lowest level at which there is no danger of overheating any part of the boiler when in operation at that level. Horizontal fire-tube types of boilers are set to allow at least 3 inches of water over the highest point of the tubes, flues, or crown sheet at the lowest reading in the gage glass.

The water-gage glasses shown in figure 15-9 are used with boilers operating at low and medium pressures. Each consists of a strong glass tube connected to the boiler or water column by two special fittings. These fittings sometimes have an automatic shutoff device, usually a nonferrous ball that functions if the water glass fails. The automatic shutoffs must be made in accordance with certain provisions of the boiler code. The following are some of these provisions: The top ball must not be capable of completely shutting off the flow; the bottom ball must rise vertically to the seat; the balls must be accessible for inspection; and provisions must be made to permit the removal and inspection of the bottom ball while the boiler is in service.

Unless two gage glasses are installed on the same horizontal line, each boiler must have three or more gage or try cocks (see figs. 15-10 and 15-11) located within the visible length of the gage glass. Boilers require only two cocks if they are not over 36 inches in diameter and heating surface does not exceed 100 square feet. Gage cocks are used to check the accuracy of the gage glass. They are opened by handwheel, chain wheel, or lever, and are closed by hand, by a weight, or spring.

WATER COLUMN

A WATER COLUMN is a hollow vessel having two connections to the boiler (see fig. 15-11.) The top connection enters the steam drum of the boiler through the top of the shell or drum. The water connection enters the shell or head at least 6 inches below the lowest permissible water level. The purpose of the water column is to steady the water level in the gage glass through the reservoir capacity of the column. Also, the column may eliminate the obstruction of small diameter, gage-glass connections by serving as a sediment chamber.

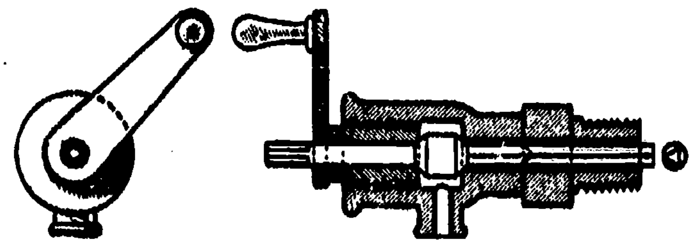

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Figure 15-10. — Try-cock.

The water columns illustrated are equipped with high- and low-water alarms which sound a whistle to warn the operator. The whistle is operated by either the two floats or the solid weights shown in figure 15-11.

WATER LEVEL CONTROL

The water level control not only automatically operates the boiler feed pump, but also safeguards the boiler against low water by stopping the burner. Various types of water level controls are used on boilers. At SEABEE activities, however, boilers frequently are equipped with a float-operated type, an electrode probe type, or a combination float and mercury switch type of automatic water level control. Each of these types is described below.

The FLOAT-OPERATED TYPE of feed-water control, similar in design to the feed-water control illustrated in figure 15-12, is attached to the water column. This control accomplishes its purpose by means of a float, arm, and set of electrical contacts. As a low water cutoff, the float rises or lowers with the water level in an enclosed chamber. The chamber is connected to the boiler by two lines which allow the water and steam to have the same level in the float chamber as in the boiler. An arm and linkage connects the float to a set of electrical contacts, which operates the feed-water pump when the water lowers the float. In the event the water supply fails or

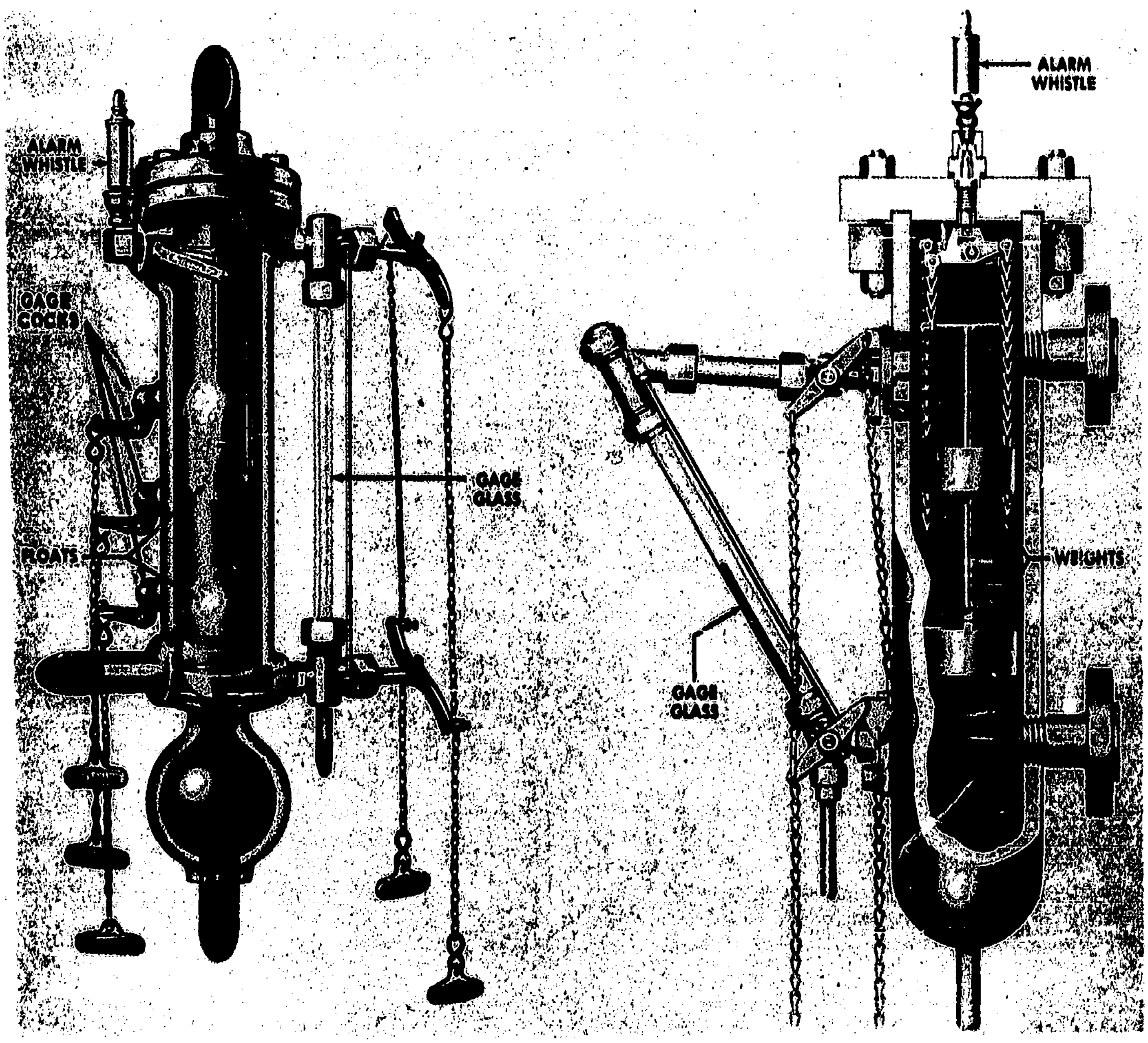

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Figure 15-11. — Typical water columns.

the pump becomes inoperative and allows the water level to continue to drop, another set of contacts operates an alarm bell, buzzer, or whistle, and secures the burners.

The COMBINATION FLOAT AND MERCURY SWITCH TYPE of water level control (see fig. 15-12) reacts to changes made within a maintained water level by breaking or making a complete control circuit to the feed-water pump. It is a simple two-position type control, having no modulation or differential adjustment or setting. As all water level controllers should be, it is wired independently from the programmer. The control is mounted at steaming water level and consists of a pressurized float, a pivoted rocker arm, and a cradle-attached mercury switch.

The combination float and mercury switch type of water level control functions as follows: As the water level within the boiler tends to

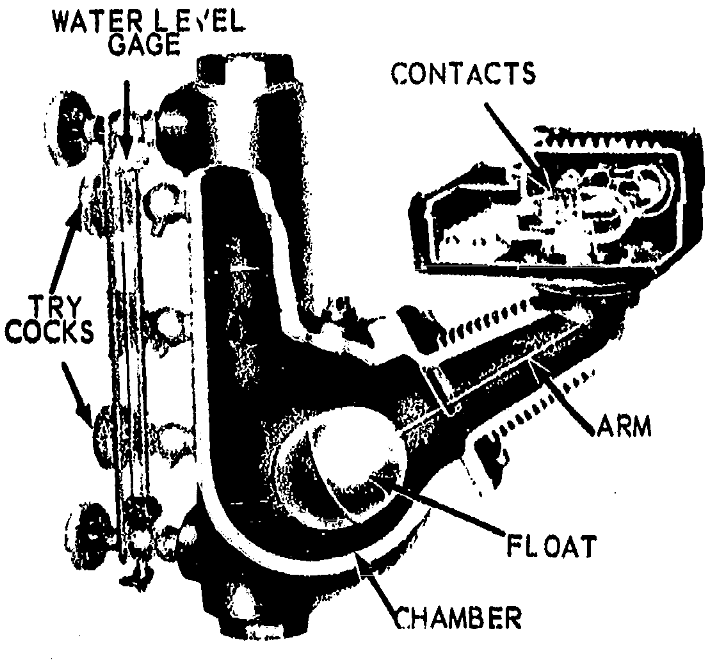

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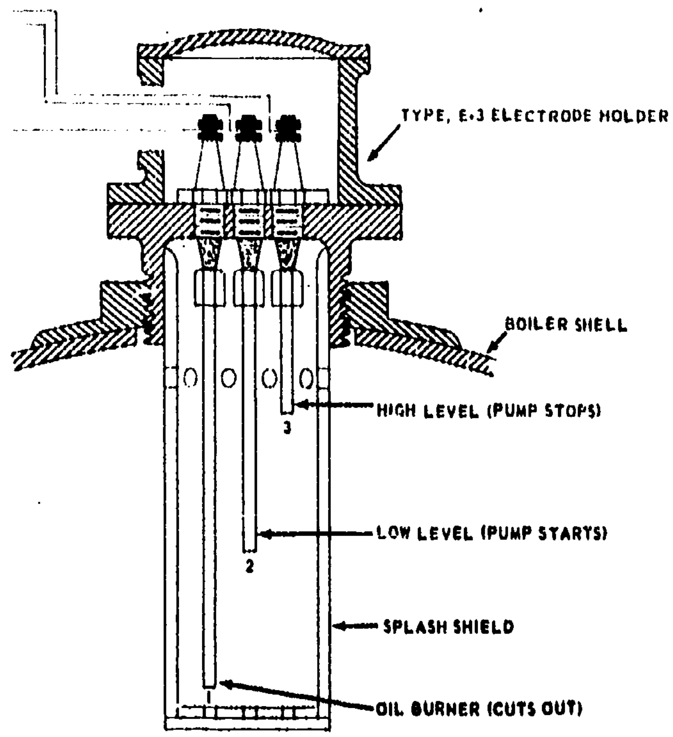
Figure 15-12.—Combination float and mercury switch type of feed-water control.



75.299
Figure 15-13.—Electrode-type water level control.

drop, the float lowers. As the float lowers, the position of the mercury switch changes. Once the float drops to a predetermined point, the mercury within the tube runs to its opposite end. This end contains two wire leads, and when connected through the puddle of mercury, completes a circuit to the feed-water pump. The pump, being energized, admits water to the boiler. As the water level within the boiler rises, the float rises. As the float rises, the position of the mercury switch changes. Once the float rises to a predetermined point, the mercury runs to the opposite end of its tube, breaking the circuit between the wire leads and securing the feed-water pump. The feed-water pump remains off until the water level again drops low enough to trip the mercury switch.

The ELECTRODE PROBE TYPE of feed-water regulating and low water cut-off control consists of an electrode assembly and a water-level relay. The electrode assembly contains three electrodes of different lengths corresponding to high, low, and cut-off water level in the boiler drum (see fig. 15-13).

The electrode assembly is installed on the top of the boiler drum so that the normal water level is at approximately the midpoint between the high-level and the low-level electrodes. The electrodes are electrically wired to the water level relay assembly. The relay contains the feed-water pump start and stop contacts wired to the feed-water pump controller, and the low water cut-off contacts wired into the burner circuit. The feed pump is started when the water level in the boiler drops below the middle electrode. After the water level is restored and reaches the high-level electrode, the feed pump is stopped. In the event the water level is not restored and drops below the longest electrode, the cut-off contacts of the water level relay stop the burner by breaking the burner circuit. The electrodes are held in position by screwing them into a threaded connector, located at the top of the electrode bottle. In some cases they also are locked in position with a suitable locking device; however, this is not a design feature common to all installations. Boiler casualties have occurred from low water cut-off electrodes backing off from threaded connectors, and grounding with the assembly bottle. On those installations where one is not present, a locking device should be installed.

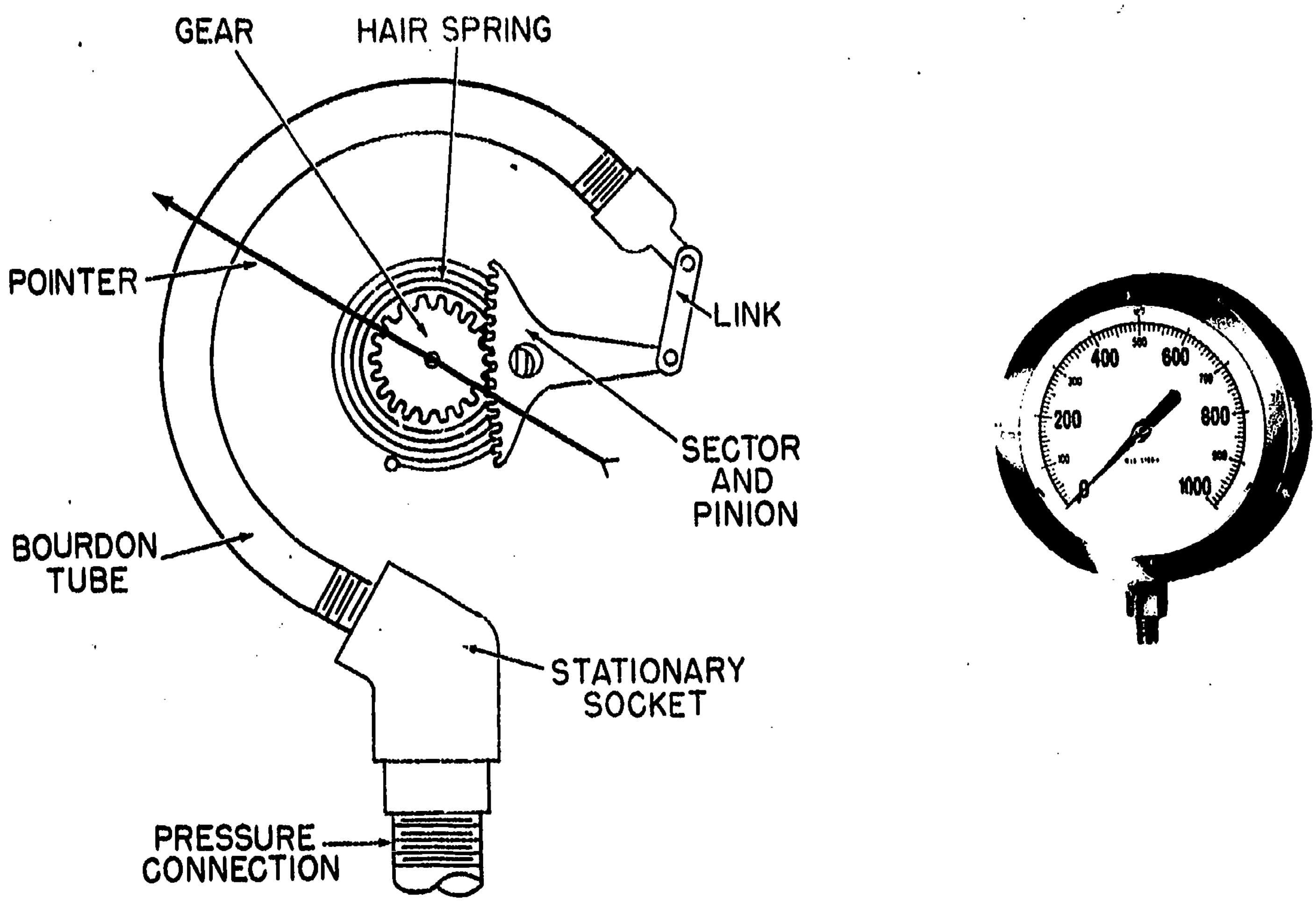


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Figure 15-14. — Bourdon-tube pressure gage.

PRESSURE GAGES

Each boiler is equipped with a PRESSURE GAGE, which serves as a means of measuring pressure. There are several types of pressure gages in common use, including the Bourdon-tube gage illustrated in figure 15-14.

The Bourdon-tube is made of seamless metal tubing and is oval in cross section. The tube is bent in the form of a letter C. One end of the tube is open and is connected to a socket that opens into the pressure line leading to the gage. The other end of the Bourdon tube is closed, and is free to move; this free end is connected to the gage pointer by a linkage system of levers and gears. The position of the free end of the Bourdon-tube represents a balance between two forces; the pressure of the liquid or gas inside the Bourdon tube which tends to straighten the tube, and the spring action of the metal which tends to coil the tube. When the pressure in the line increases, the tube straightens out slightly and the free end moves away from the center. This movement operates the linkage system and moves the pointer to a higher reading on the dial. When the pressure in the line decreases, the free end of the Bourdon tube moves toward the center and moves the pointer to a lower reading on the dial.

The gage should be tested semiannually, or whenever there is any reason to doubt its accuracy. A gage cock or shut-off valve will be installed between the pressure gage and pressure source so that the pressure gage can be removed or repaired without relieving pressure in the boiler.

A pressure gage must be accurately calibrated and have a loop of tubing called a siphon (or pigtail) between the boiler and the gage

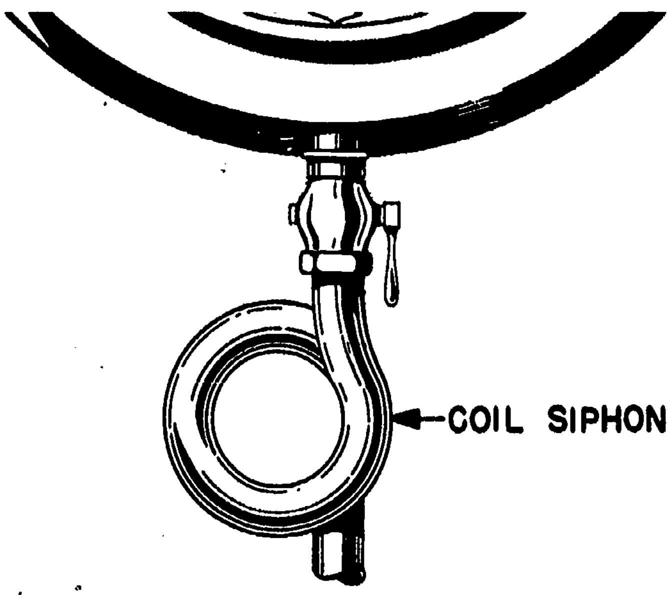

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Figure 15-15.—Siphon (or pigtail).

(see fig. 15-15). The exposed (uninsulated) coil is provided in the line leading to the gage, and the steam condenses into water in this exposed coil. Thus there is always a condensate seal between the gage and steam source. Sometimes the condensate seal is lost when repairs are made to the gage or to the gage line; in this event, the loop must always be filled with water before the gage is subjected to steam line pressure.

FUSIBLE PLUGS

FUSIBLE PLUGS are used on some boilers to provide added protection against low water. They are constructed of bronze or brass with a tapered hole drilled lengthwise through the plug. They have an even taper from end to end. This tapered hole is filled with a low-melting alloy consisting mostly of tin. There are two types of fusible plugs: fire-actuated and steam-actuated.

The FIRE-ACTUATED type is filled with an alloy of tin, copper, and lead, with a melting point of 445° to 450° F. It is screwed into the shell at the lowest permissible water level. One side of the plug is in contact with the fire or hot gases, and the other side is in contact with the water. As long as the plug is covered with water, the tin does not melt. If the water level drops below the plug, the tin melts and is blown out. The boiler then must be taken out of service to replace the plug.

The STEAM-ACTUATED type of fusible plug is installed on the end of a pipe outside the drum. The other end of the pipe, which is open, is at the lowest permissible water level in the steam drum. A valve is usually installed between the plug and the drum. The metal in the plug melts at a temperature below that of the steam in the boiler. The pipe is small enough to prevent water from circulating in it. The water around the plug is much cooler than the water in the boiler as long as the end of the pipe is below the water level. However, if the water level drops below the open end of the pipe, the cool water runs out of the pipe and steam heats the plug. The hot steam melts the tin and it is blown out by the steam, warning the operator. This type of plug can be replaced by closing the valve in the plug line. It is not necessary to take the boiler out of service to replace the plug.

Fusible plugs should be renewed regularly once a year. DO NOT refill old casings with new tin alloy and use again. ALWAYS USE A NEW PLUG.

VALVES

Boiler fittings include various types of valves, and each type is designed to serve a special purpose. With that thought in mind, let us consider some of the common types of valves, their location, and function.

The MAIN STEAM STOP VALVE is located at the steam outlet of the boiler. The bearing surfaces on the valve disk and seat are usually made of a very hard erosion-resisting alloy, called STELLITE. Drain connections are sometimes fitted to the underside of the valve body, on either side of the valve disk. These drains can be used as bypass valves to equalize the pressure on both sides of the disk to facilitate opening of the main steam stop valve and to ensure proper drainage of that section of the main steam line. The main steam stop valve is either fully open or fully closed. The purpose of this valve is to put the boiler on the line, or to secure it.

A FEED STOP VALVE AND A STOP-CHECK VALVE are installed on Navy boilers for shutting off the flow of feed water, and controlling the flow of feed as desired. Check valves are located between the feed stop valve and the feed pump to eliminate any possible back pressure on the feed pump and condensate tank.

The SURFACE BLOW VALVE (when installed) is located on the steam drum where it connects to the surface blow line which terminates at a scum pan inside the drum. This pan is located just below the normal water line. Its purpose is to remove scum from the surface of the water. As with most high-pressure valves of the globe type, the pressure is directed under the seat to facilitate opening.

BOTTOM BLOW VALVES, installed at the bottom of each water drum and header, are used to blow down the boiler, removing scale and other foreign matter that has settled in the lowest part of the water spaces. Boilers are also blown down to control concentration of solids dissolved in boiler water. Blow-down valves are located at the lowest point of the water sides.

The SAFETY VALVE is the most important of boiler fittings. It is designed to open automatically to prevent pressure in the boiler increasing beyond the safe-operating limit. It is installed, in a vertical position, directly to the steam space of the boiler. Each boiler has at least one safety valve; if the boiler has more than 500 square feet of heating surface, two or more valves are required. There are several different types of safety valves in use, but all are designed to open completely (POP) at a specified pressure, and to remain open until a specified pressure drop (BLOWDOWN) has occured. Safety valves must close tightly, without chattering, and must remain tightly closed after seating.

It is important to understand the difference between boiler safety valves and ordinary relief valves. The amount of pressure required to lift a relief valve increases as the valve lifts, because the resistance of the spring increases in proportion to the amount of compression. If a relief valve were installed on a steam drum, therefore, it would open slightly when the specified pressure was exceeded; a small amount of steam would be discharged; and then the valve would close again. Thus a relief valve on a steam drum would be constantly opening and closing; and this repeated action would pound the seat and disk and cause early failure of the valve. In order to overcome this difficulty, safety valves are designed to open completely at a specified pressure.

Several different types of safety valves are used on boilers, but they all lift on the same general principle. In each case the initial lift of the valve disk or feather is caused by static pressure of the steam acting upon the disk or feather. As soon as the valve begins to open, however, a projecting lip or ring of larger area is exposed for the steam pressure to act upon. The resulting increase in force overcomes the resistance of the spring, and the valve pops — that is, it opens quickly and completely. Because of the larger area now presented, the valve reseats at a lower pressure than that which caused it to lift originally.

Lifting levers are provided to lift the valve from its seat (when boiler pressure is at least 75 percent of that at which the valve is set to pop), to check the action, and to blow away any dirt from the seat. When the lifting lever is used, raise the valve disk sufficiently to ensure that all foreign matter is blown from around the seat to prevent leakage after being closed.

The various types of safety valves differ chiefly as to the method of applying compression to the spring, the method of transmitting spring pressure to the feather or disk, the shape of the feather or disk, and the method of blowdown adjustment. Detailed information on the operation and maintenance of safety valves can be found in the instruction books furnished by the manufacturers of this equipment.

The AIR COCK is a valve located at the highest point of the steam space. Two important purposes of this valve are: (1) to allow air to escape while raising steam on a cold boiler or when filling a boiler with water; and (2) to allow air to enter when draining a boiler. When lighting off a cold boiler the air cock is one of the first valves to open. It is closed when sufficient steam has been generated to displace all the air in the steam space.

The ROOT VALVE is an emergency shut-off valve located between the source of pressure and the supplied equipment. An example is the valve located between the main steam stop valve and the main steam line. This valve must be capable of withstanding maximum operating pressure.

OIL BURNER

The oil burner serves a vital function in the operation of a steam boiler, since its purpose, primarily, is to PREPARE THE FUEL FOR COMBUSTION. Two types of oil burners which may concern you in your work are direct-drive and belt-drive burners.

The DIRECT-DRIVE type of burner is built up from a rotating mainshaft, which is actually an extension of the motor shaft. The mainshaft extends through the burner length. It carries the motor rotor, fan, oil atomizer, and the pump drive worm. The shaft bears two ball-bearing races, located in the gear case housing. The shaft speed is nominally 3,450 rpm.

The BELT-DRIVE type of burner depends on pulleys and V-belts to drive the burner shaft. The motor is mounted on the gear case housing. Using a standard 1,725 rpm motor the pulley ratio is 2:1, resulting in a nominal speed of 3,450 rpm. If other speed motors are used, the pulley ratios are proportioned to obtain a burner shaft rpm of 3,450. The belt-drive burner carries the same rotating elements as the direct-drive burner with the exception of the rotor.

The oil ATOMIZER is the heart of the entire burner system. Hence, it is appropriate that we point out a few main details concerning the design and function of this important device.

The UT is likely to find two types of mechanical atomizers used on Navy boilers—pressure and rotary. In the ROTARY type atomizer, oil is fed through a stationary tube to the inner surface of an atomizing cup. The oil spreads over the surface of the rotating cup, and on reaching the edge of the cup is thrown off. The rotating cup imparts a whirling motion to the oil as it travels to the edge, and the resulting centrifugal force breaks up the oil into fine particles as it leaves the cup. A current of air from the fan flows around the atomizing cup and is given a whirling motion in the direction opposite to that of the oil. The streams of air and oil collide and are thoroughly mixed.

The amount of air supplied by the fan can be regulated by a damper on the suction side. This damper is usually controlled, together with the oil supply, by automatic or manual controls. The shape of the flame is determined by the nozzle through which the air is discharged.

PRESSURE type atomizers are commonly used on burners of small heating units. Detailed information on pressure atomizers is given in chapter 20 of this manual.

Regardless of the type of burner used, the angle of flame, as well as gallons of fuel per hour, must be controlled to coincide with the size and shape of the combustion chamber (fire box). Different types of burners will use different methods of combustion; therefore, the manufacturer's instructions should be used when and where available.

STEAM INJECTOR FEED SYSTEM

The STEAM INJECTOR is a boiler FEED PUMP which utilizes the velocity and condensation of a jet of steam from the boiler to lift and force a jet of water into a boiler. This injection of water is many times the weight of the original jet of steam.

The injector is used to some extent in boiler plants as an emergency or stand-by feed unit. It will not feed very hot water. Under best conditions, it will lift 120° water about 14 feet.

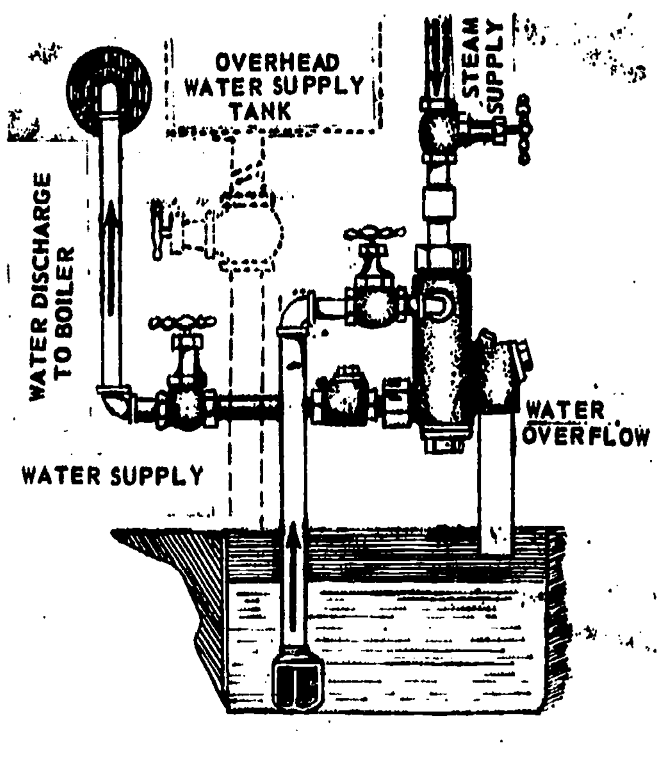

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Figure 15-16.—Injector piping.

The installation of an injector is not a difficult operation. The unit is mounted on the side of the boiler. Four connections (see fig. 15-16) are made to the injector: the steam supply line from the boiler, the water supply line from a reservoir, the discharge line to the boiler feed-water inlet, and the water overflow line.

The controls include a steam supply valve, water supply valve, discharge valve to the boiler, and a check valve in the discharge line.

A cross sectional view of an injector is shown in figure 15-17. The illustration has been labeled to show the name and location of various important parts of the injector.

As you might expect, some degree of skill is needed to start the injector. After beginning to operate, however, it continues automatically until shut down by the operator. When starting the injector, first open the water supply valve about one full turn. Next, quickly turn the steam supply valve all the way open. At this point steam rushes into the combining tube of the injector. As the steam speeds past the water supply opening it creates a suction that draws water through the opening into the combining tube. Water and steam are now mixed together inside the injector and the pressure opens a valve that leads to the boiler. Meanwhile, there is an excess of water in the injector; this excess is discharged through an overflow valve. As the next step of the procedure, slowly turn the water supply valve toward the closed position until the overflow stops. The overflow valve has now closed and all of the water being picked up from the supply line is going into the boiler. Remember that this feed-water system is used on boilers as a stand-by method of feeding water.

The water supply should not be hotter than 120° F for the injector to operate. In case several unsuccessful attempts are made to operate the injector, it will become very hot and cannot be made to prime. If you should encounter this problem, pour cold water over the injector until it is cool enough to draw water from the supply when the steam valve is opened.

AUTOMATIC CONTROLS

Automatic controls are a big asset since they reduce manual control of the furnace,

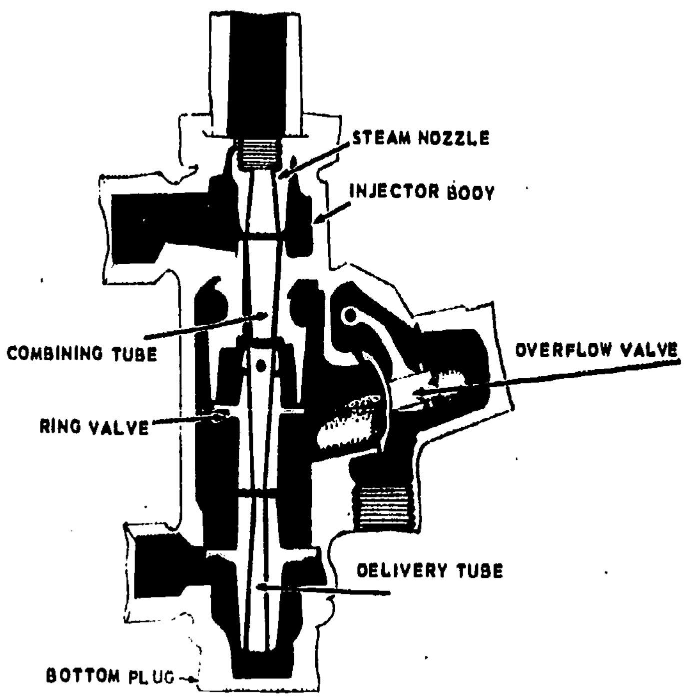

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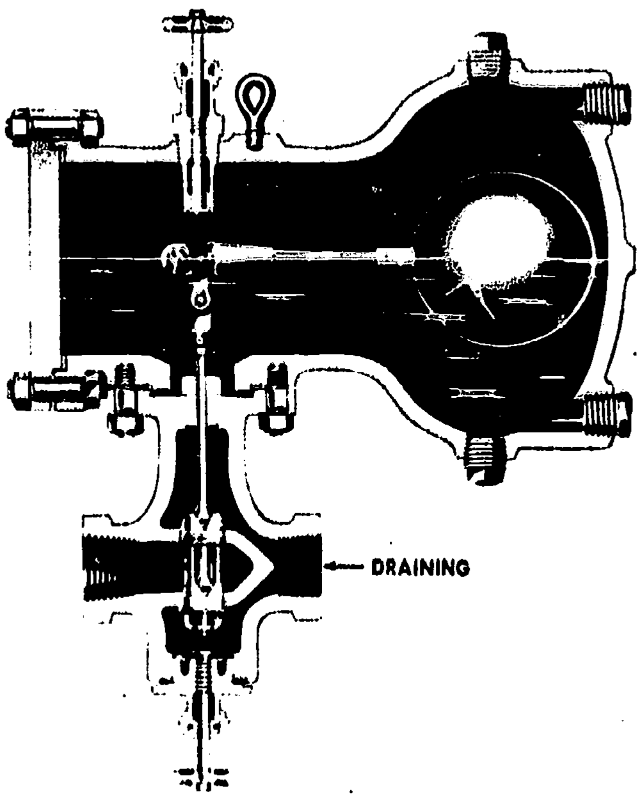
Figure 15-17. — A cross sectional view of an injector.



54.130
Figure 15-18. — Float controller.

boilers, and auxiliary equipment. Four types with which the UT should be familiar are: (1) float controller, (2) pressure controller, (3) combustion controller, and (4) flame failure and operation controls.

FLOAT CONTROL

Floats in boiler controls work on the same basic principle as the float in the flush-tank type of water closets. Float, or level control,

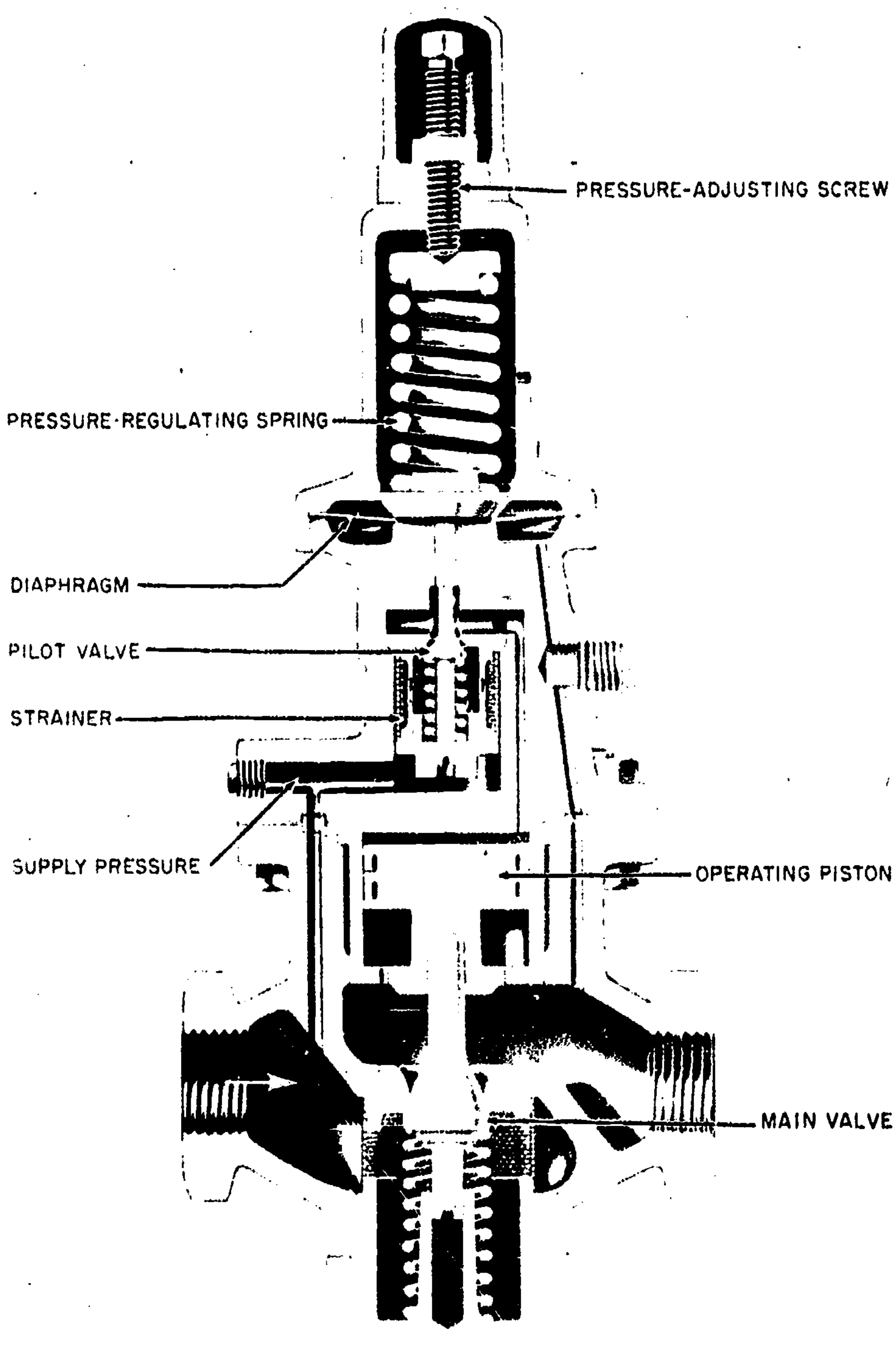


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Figure 15-19. — Pressure regulator.

depends on the level of fluid in a tank or boiler to indicate the balance between the flow out of and the flow into the equipment, and to operate a controller to restore the balance.

A float is often used to measure the change in level and to operate the controlled valve to restore the balance. It may be arranged to increase the flow when the level drops. Figure 15-18 illustrates one of the methods used to accomplish this. Here the float is connected to the control valve.

PRESSURE REGULATING CONTROL

Pressure regulating is the process of maintaining a difference of pressure between two points in the system. One type of pressure regulating maintains a definite pressure in one part of the system, while the other part fluctuates or changes within certain limits. An example of this type of control is a pressure-reducing valve which maintains a definite pressure on the discharge side of the valve by controlling the flow of steam, air, or gas through the valve (see fig. 15-19).

A second type of regulator maintains a definite difference in pressure between two points,

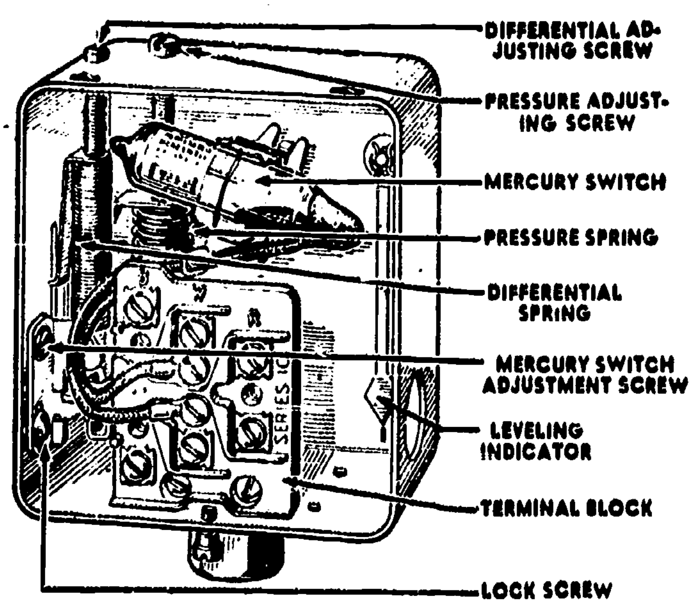

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Figure 15-20. — Typical pressure control with a differential range from 0 to 10 pounds.

and also controls the flow. This type of regulator is often applied to boiler feeding to maintain a fixed difference between the pressure of water supplied at the feed valve and the pressure in the boiler steam drum. The pressure regulator may consist of a self-contained device which operates the regulating valve directly, or it may consist of a pressure measuring device such as a Bourdon-tube gage which operates a pilot or relay valve. The valve positions the regulating valve or mechanism to maintain the desired conditions.

An electrical pressure controller can be used to maintain pressure between two given points. (See fig. 15-20) This type of control is often applied to boiler steam pressure to cut in the burner on a set low pressure, and to cut out the burner on a set high pressure. It may also be used to control air, liquid, or noncombustible gases, providing their chemical content is not injurious to the control. Its design includes a bellows, which actuates a switch to make or break an electrical circuit in response to variations in pressure. Some types contain a mercury switch, others employ a snap switch. The electrical pressure controller is located above the water line. It is mounted in a fitting provided by the manufacturer or beside the pressure gage. A siphon (pigtail) must always be connected between the pressure control and the boiler, with the loop towards the front or back of the control.

COMBUSTION CONTROL

Combustion control is the process of regulating the mixed flow of air and fuel to a furnace as necessary to supply the demand for steam. A modulating pressuretrol controls the movement of the modutrol motor which, in turn, opens or closes the oil valve and air shutters in order to adjust the rate of firing to suit the demands of the boiler. Figure 15-21 shows a modulating motor. The modulating motor consists of the motor windings, a balancing relay, and balancing potentiometer. The loading is transmitted to the winding through an oil-immersed gear train from the crank arm. The crankshaft is the double-ended type and the crank arm may be mounted on either end of the motor. The motor works in conjunction with the potentiometer coil in the modulating pressuretrol. Electrical unbalance is created by pressure change signals to the pressuretrol. This causes the motor to rotate in an attempt to rebalance the circuit. The crank arm, through

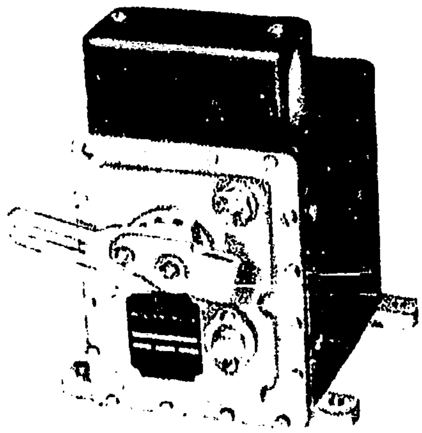

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Figure 15-21. — Modulating motor.

linkage, positions the burner air louvers and the oil regulating valve, maintaining a balanced flow of air and oil throughout the burner firing range.

FLAME FAILURE AND OPERATION CONTROLS

Frequently, on full-automatic boilers, you will find an electronic-type device provided for the control of flame failure. The device will provide automatic start and operation of the main burner equipment. The controls are so designed that they close all fuel valves, shut down the burner equipment within 4 seconds after a flame failure, and actuate an alarm. The controls also create a safety shutdown within 4 seconds after deenergization of ignition equipment if the main burner flame is not properly established or fails during the normal starting sequence. The controls must create a safety shutdown if the pilot flame is not established and confirmed within 7 seconds after lighting. A safety shutdown requires manual reset before operation can be resumed and prevents recycling of the burner equipment.

In all initial starts and subsequent restarts during on-and-off cycling the automatic operation controls are designed to provide the following services:

Low fire start.

Precombustion and postcombustion scavenging, except for fully automatic boilers having capacities of 2,000 lbs per hour or less, which require no postcombustion scavenging (during pre- or post-combustion scavenging periods the blower should be on, and the ignition, pilot, and main fuel valve should be off).

Time delay of at least 5 seconds between ignition of the pilot and opening of the main fuel valve (except for gas-fired boilers and light oil-fired boilers with pilot, the pilot flame must be established and confirmed before opening of the main fuel valve).

Trial-for-main-burner-ignition period. Note that the trial-for-ignition period is the time the pilot flame and/or ignition is on after the main fuel valve opens.

Proper shift of operation from operating control to the combustion operating controls after the main burner flame has been properly established and confirmed.

In case of supply voltage failure, the operating control will recycle when power is restored. The electronic device should readily detect flame under all firing conditions of both pilot and main flame, but should not be actuated by hot refractory or any other hot body. The controls are designed so that failure of any vacuum tube or other component will cause a safety shutdown, or result in a safety interlock to prevent recycling of the control.

A typical and modern combustion safety device is the electronic type using a photocell (or electric eye) to detect the presence of an oil flame. (See fig. 15-22) This is a fast acting device and is referred to by such names as flame eye, scanner, and electric eye. The photocell reacts to the light of the oil flame, thereby

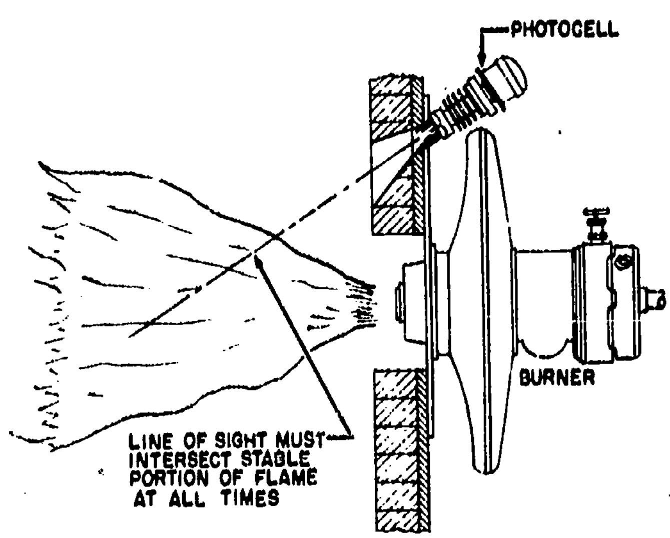

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Figure 15-22. — Photocell (electric eye).

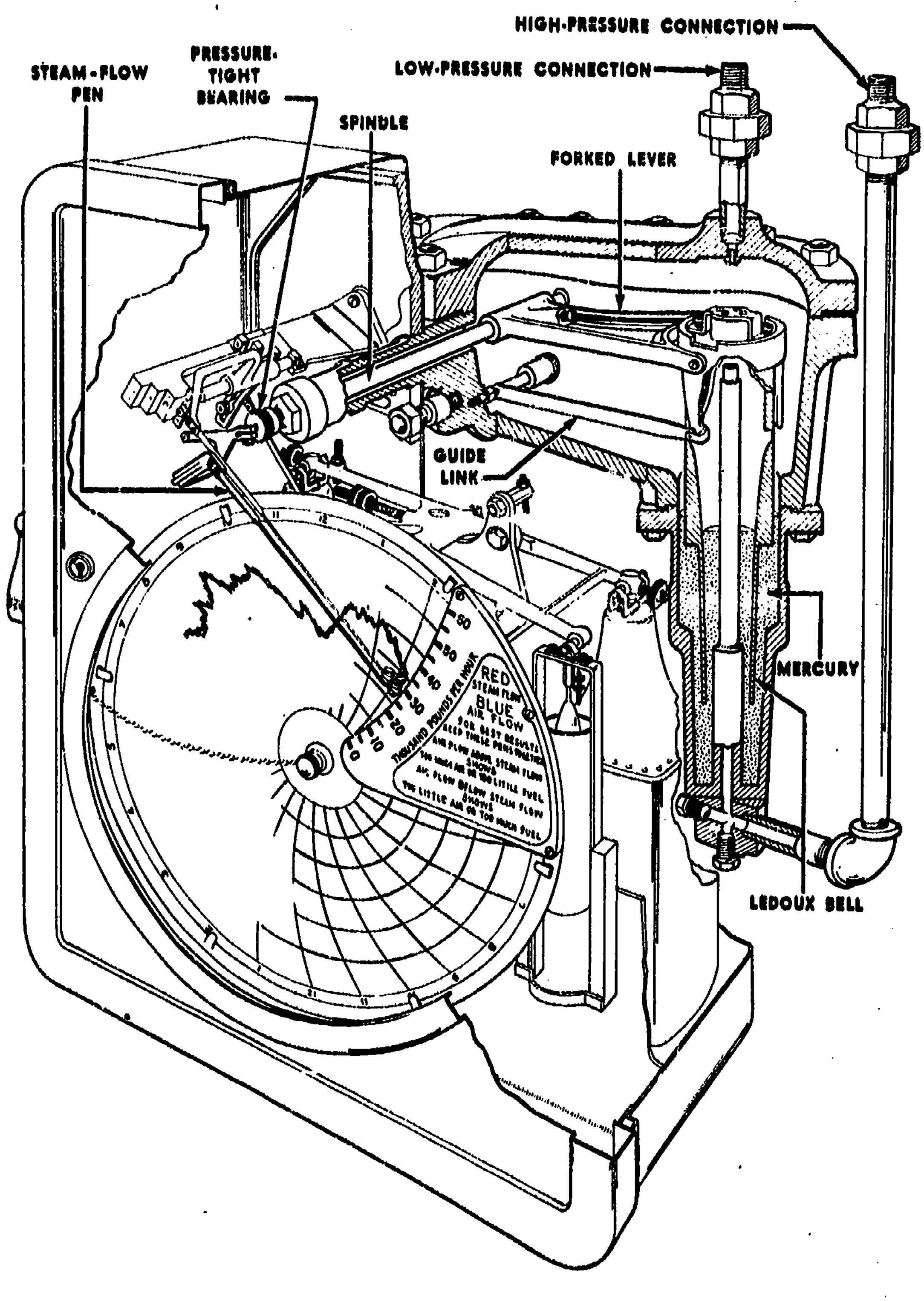

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Figure 15-23. — Flow meter.

allowing current to flow in the electronic circuit and holding the flame relay in a closed position. A failure of the flame interrupts the electronic circuit causing the burner to shut down on safety. The photocell is provided with a time delay of 4 to 8 seconds in order to prevent nuisance shutdowns due to fluctuations in flame, especially at low fire positions.

INSTRUMENTS AND METERS

A pressure gage is essential for safe operation of a boiler plant. However, use of additional instruments, such as draft gages and flow meters, increases safety and promotes efficiency. All of these instruments may be either indicating or recording.

STEAM FLOW METERS

Meters used to measure quantities may be divided into two general types: those indicating rate, such as flow meters; and those indicating the total, such as scales. Many devices measure and indicate the pressure of steam flow. One is illustrated in figure 15-23. This meter uses a weighted inverted bell (called a Ledoux bell) sealed with mercury. The bell moves up and down as the rate of flow changes. The movement is transmitted to a pen which records the flow.

STEAM-FLOW AIR-FLOW METER

A combustion air- and steam-flow meter is shown in figure 15-24. This meter is used as a guide in controlling the relationship between air required and air actually supplied to burn the fuel. The rate of steam generation is used as a measure of air necessary to burn the required amount of fuel. The flow of gases through the boiler setting is used as a measure of air supplied.

Essential parts of the meter are two airflow bells supported from knife edges on a beam, which is supported by other knife edges, and a mercuty displacer assembly supported by a knife edge on the beam. The bottoms of the bells are sealed with oil and the spaces under the bells are connected to two points of the boiler setting.

DRAFT GAGES

A draft gage is a form of pressure gage. In boiler practice, the term "draft" usually refers to the pressure difference producing the flow. Drafts are pressures below atmospheric pressure. They are measured in inches of water. A draft gage is essential to boiler operation. Its use increases the safety of operation.

A simple type of draft gage is the U-tube gage. The source of draft is connected to one leg of the U and the other end is left open. The difference between the levels of the liquid in the two legs is a measure of the draft. Water is generally used in this type of gage. Take a

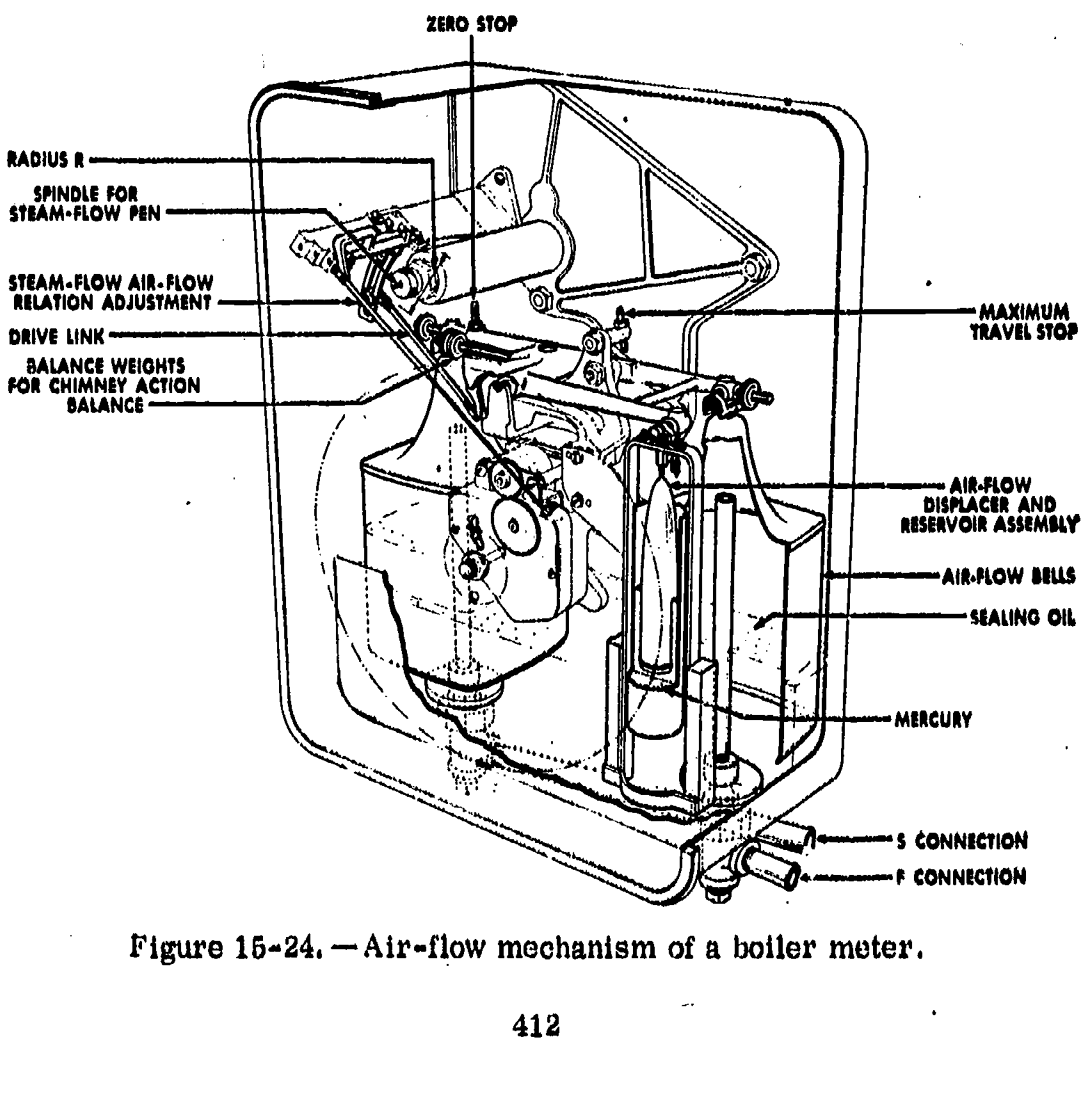

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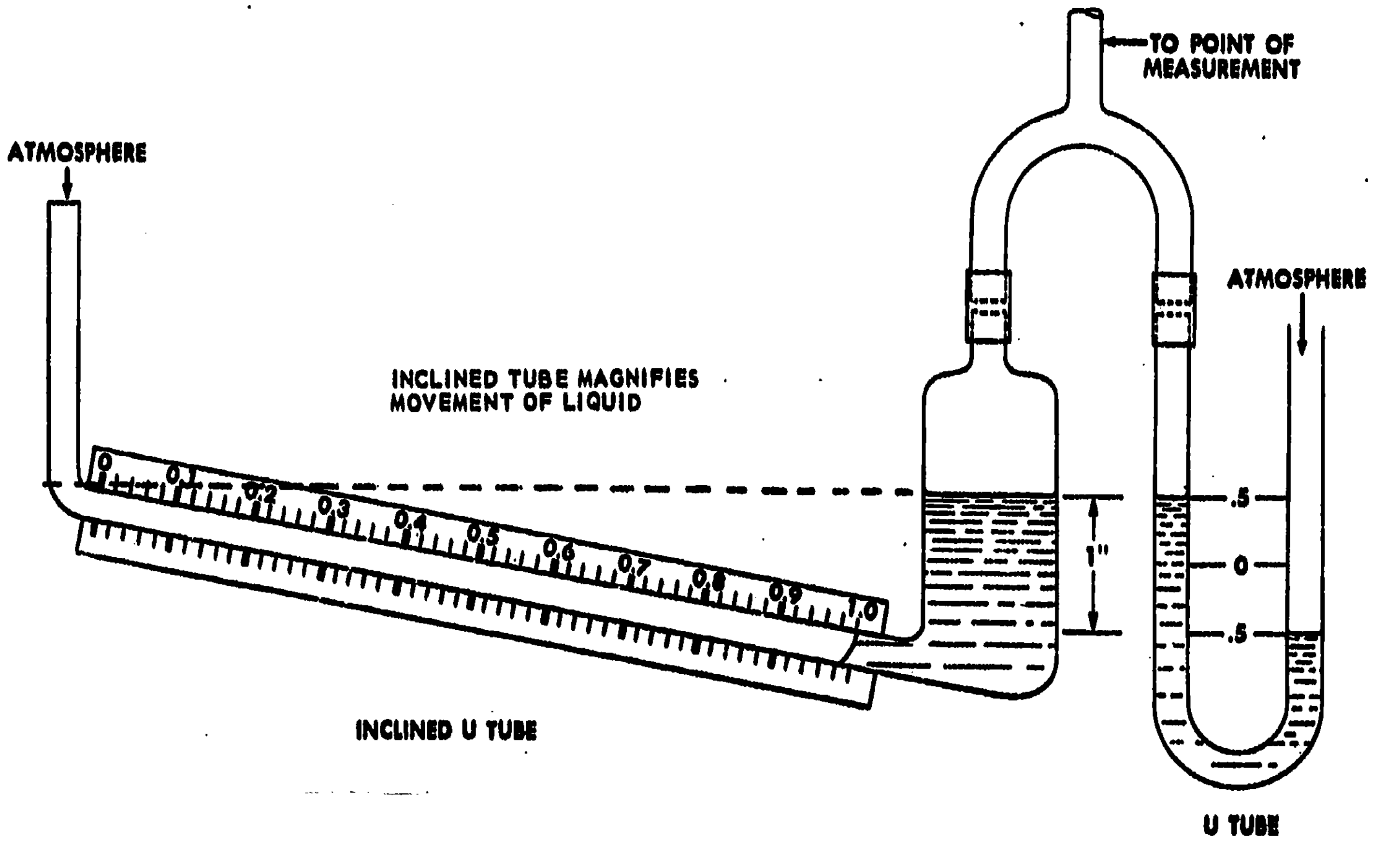
Figure 15-24. —Air-flow mechanism of a boiler meter.



54.137

Figure 15-25. —Comparison of inclined draft gage and U-tube gage.

close look at figure 15-25, which shows a comparison of an inclined draft gage and a U-tube gage.

If one leg of the U-tube is arranged on an incline, the distance moved by the liquid in the inclined portion is increased for a given draft change, which makes more accurate reading possible.

Two or more draft gages are required for economical boiler operation. They inform the operator of the relative amount of air being supplied to burn the fuel and the condition of the gas passages. Draft gages are made as indicators, recorders, or both. The measuring element uses a column of liquid, a diaphragm, or a bellows. The liquids used are oil, water, or mercury.

The gage shown in figure 15-26 is an indicating type which operates on the same principle as the U-tube (difference between the levels of the liquid in the two legs is a measure of the draft).

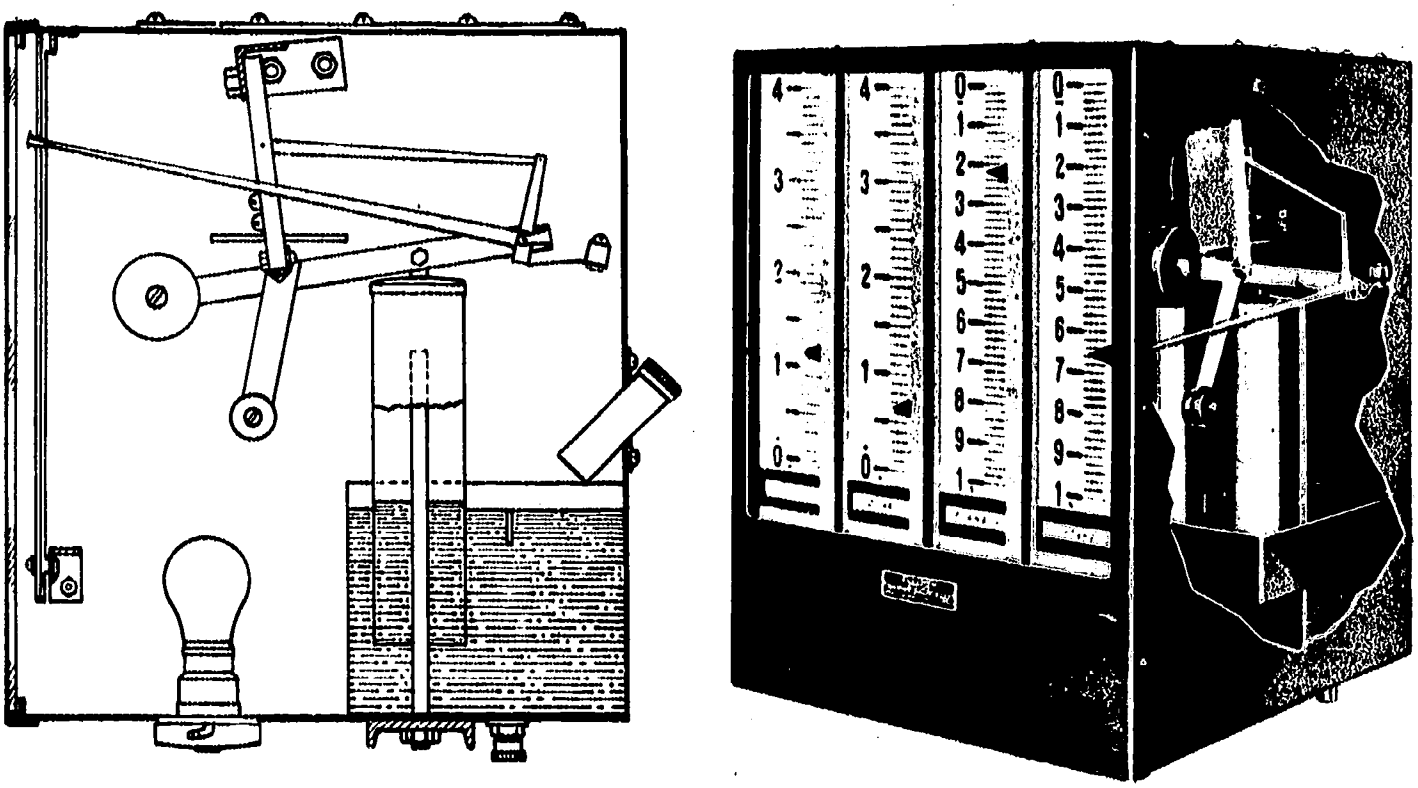
The bottom of the inverted bell is sealed with oil or mercury, depending on the magnitude of the draft or pressure to be measured. It is supported by knife edges on the beam to reduce friction as much as possible. The weights counterbalance the weight of the bell, and the pointer is returned to zero. The source of draft is connected to the tube which projects into the inverted bell so that an increase in draft causes the pointer to move down.

CO_2 METER

Figure 15-27 shows a carbon dioxide meter for determining, indicating, and recording the percentage of CO_2 (carbon dioxide) in the products of combustion. The principle of this instrument is based on the fact that the specific weight of flue gas varies in proportion to its CO_2 content (CO_2 being considerably heavier than the remaining parts of the flue gas).

STEAM TRAPS

Steam traps are automatic devices which drain condensate, and stop the passage of uncondensed steam through the drain lines. Accumulation of condensate may seriously affect



54.138

Figure 15-26. — Liquid-sealed draft gage.

the performance of steam distribution lines by decreasing the capacity for heat transmission. Also, condensate may produce water hammer which can result in burst pipes and blown gaskets.

In general, traps have the following components:

1. A vessel to collect the condensate.

2. An orifice through which the condensate is discharged.

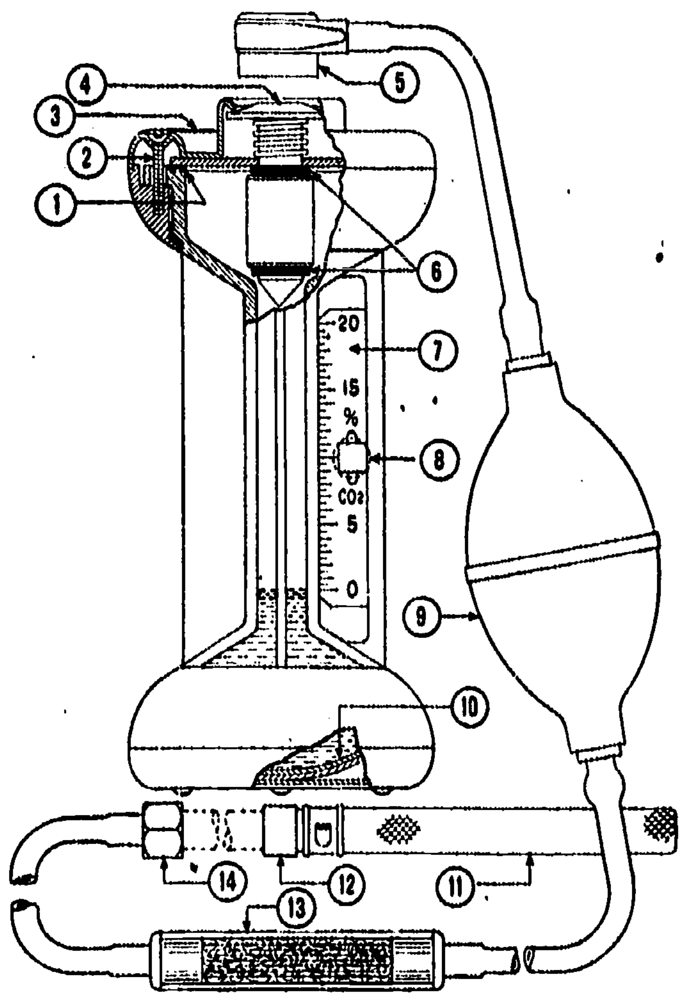
3. A valve to close the orifice.
4. Adequate mechanisms to operate the valve.

5. An inlet opening to the vessel for condensate admission.

6. An outlet opening for condensate discharge.

INSTALLATION

Drip piping to traps should be of the same weight and material as the drained piping. Traps may be discharged through a check valve into a pumped condensate line if the pressure differential through the trap is adequate. Preferably, however, a discharge line from a trap should run separately to a gravity condensate return main or to a nearby flash tank. The discharge piping from a trap should be pitched down, at a minimum of 3 inches per 100 feet, to the collection tank of a condensate pump set, or to a gravity return. This slope is not required, however, when there is sufficient pressure in the steam line to overcome the friction and static head in the discharge line, whether level or pitched up. If it is impractical to return drips to a condensate system, they may be drained as waste to a sewer. When the temperature of the drains exceeds sewer limitations, the condensate must be cooled in a sump or by other means. Some traps are provided with a built-in strainer. When this is not the case, a strainer should be installed ahead of the trap to act as a catch-pocket for pipe scale, sediment, and foreign materials. For testing convenience, trap installations should include a tee and test valve in the discharge line to check trap action. When it is required to ensure continuity of service, a three-valved bypass should be installed around



1 Gasket
2 Top cap holding screw
3 Top cap
4 Plunger cap
5 Connector tip
6 Plunger seats
7 CO_2 scale
8 Scale locking screw
9 Rubber aspirator bulb
10 Bottom of analyzer
11 Filter nipple
12 Connection sampling tube to filter nipple
13 Filter tube
14 Connection tubing to sampling tube

54.410

Figure 15-27. — CO_2 meter.

the trap. This permits drainage of the line when the trap is out of service for repairs.

BIMETALLIC-ELEMENT TRAP

The bimetallic-element actuated steam trap, illustrated in figure 15-28, is a desirable trap for systems with fluctuating pressures or changing characteristics. The initial cost of this trap not only is moderate, but its upkeep especially low. Other advantages worth noting are that it has few moving parts, and it will not blow steam. With the exception of the thermal element, this trap is suitable for use on systems with pressures ranging from 10 to 600 psi, or working temperatures up to 800 degrees.

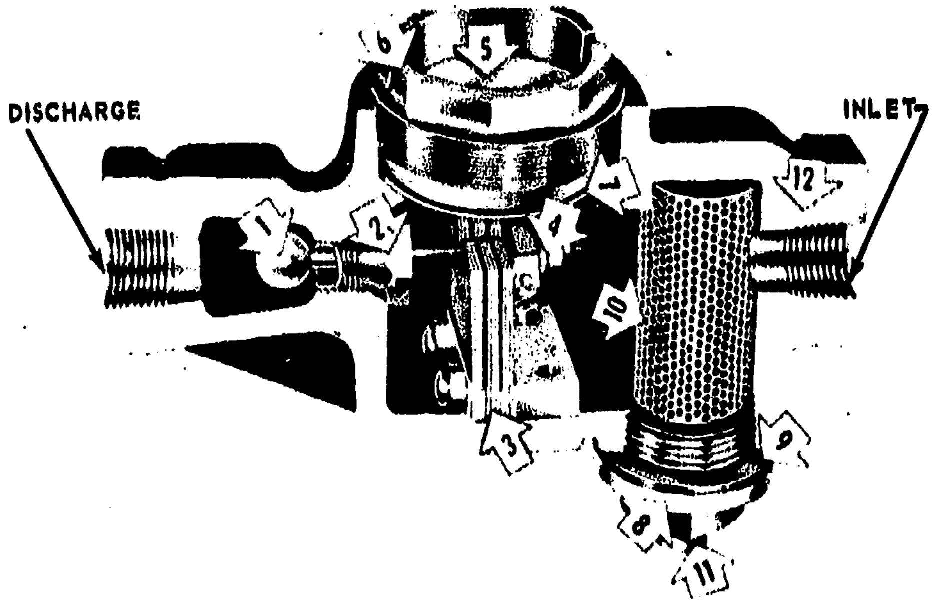
Using a bimetallic-element trap on high or low steam pressure systems is simply a matter of increasing or decreasing the number of metallic leaves in the trap. If alloy steel bodies are specified you can use these traps on systems with pressures up to 2000 psi, or working temperatures up to 1,000° F.

BUCKET TRAPS

Bucket traps can be of the open top or the inverted type. Both use the difference between the density of steam and condensate for their operation. Cooled condensate is not required to operate traps which release condensate at steam temperature. Figure 15-29 illustrates an inverted bucket trap. When the trap is first installed and steam is turned on, the inverted bucket is down and the valve is wide open. Condensate enters under the bell or inverted bucket and flows through the discharge orifice. After all the condensate is removed, steam reaches the trap and floats the bucket, closing the valve. When condensate enters the trap, the bucket loses its buoyancy and drops. This opens the valve and the condensate is discharged until the steam again floats the bucket, closing the valve.

FLOAT AND THERMOSTATIC TRAP

The float and thermostatic trap, illustrated in figure 15-30, also depends for its operation on the difference in density between the steam and the condensate. In operation, condensate that collects in the trap body gradually raises the float, thus opening the discharge valve through a lever mechanism. After the condensate is discharged, the float drops, closing the valve and preventing the passage of steam. Air and noncondensable gases are relieved through a thermostatic vent. The thermostatic vent consists of a bellows and valve assembly. The chamber inside the bellows is filled with a liquid, or has a small amount of volatile liquid, such as alcohol. In operation, the liquid expands or vaporizes when steam contacts the expansive element. The pressure developed expands the element and closes the valve, preventing the passage of steam. When relatively cool condensate, or air, contacts the element, the vapor condenses or the liquid contracts,



1. Ball valve, chrome steel, mirror finish.
2. Valve seat, corrosion-resistant steel.
3. Bimetallic thermal unit.
4. Discharge temperature setter.
5. Optional observation glass, heat resistant.
6. Cover plate.
7. Gaskets, asbestos - metal.
8. Removable strainer plug.
9. Gasket, asbestos - copper ring type.
10. Strainer basket, phosphor bronze mesh or corrosion - resistant steel.
11. Drain plug for cleaning while in operation.
12. Body, semi-steel, cast steel, or alloy steel.

11.325(54)C

Figure 15-28. — Bimetallic-element steam trap.

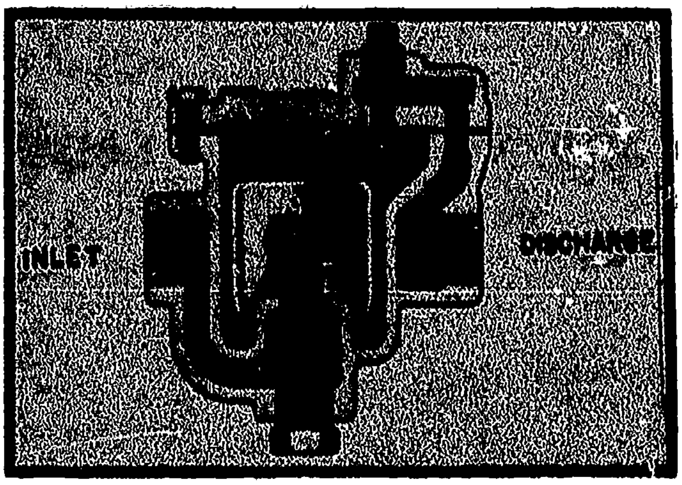
thus decreasing the pressure and opening the valve which permits the air and condensate to flow. The discharge from this type of trap is intermittent. A cooling leg of 3 or 4 feet should be provided ahead of the trap. Some thermostatic elements employ metal diaphragms in place of bellows: but the operating principle is identical.

IMPULSE TRAP

The impulse trap depends for its operation on the throttling effect of the flash steam generated when condensate is passed through orifices. (See fig. 15-31.) In operation, condensate builds up pressure below the control disk lifting the valve like a piston. Condensate is discharged while a small portion of the condensate (called control flow) flows up around the disk to the lower pressure control chamber. The pressure in this chamber remains low as it is relieved through an orifice in the valve body to the trap outlet side. When condensate reaches near-steam temperature, part of the control flow flashes into steam because of the reduced pressure in the control chamber. The increased volume chokes off some of the flow through the control orifice, building up the pressure in the chamber. This causes the valve to close, shutting the discharge, except for the small amount flowing through the control orifice.

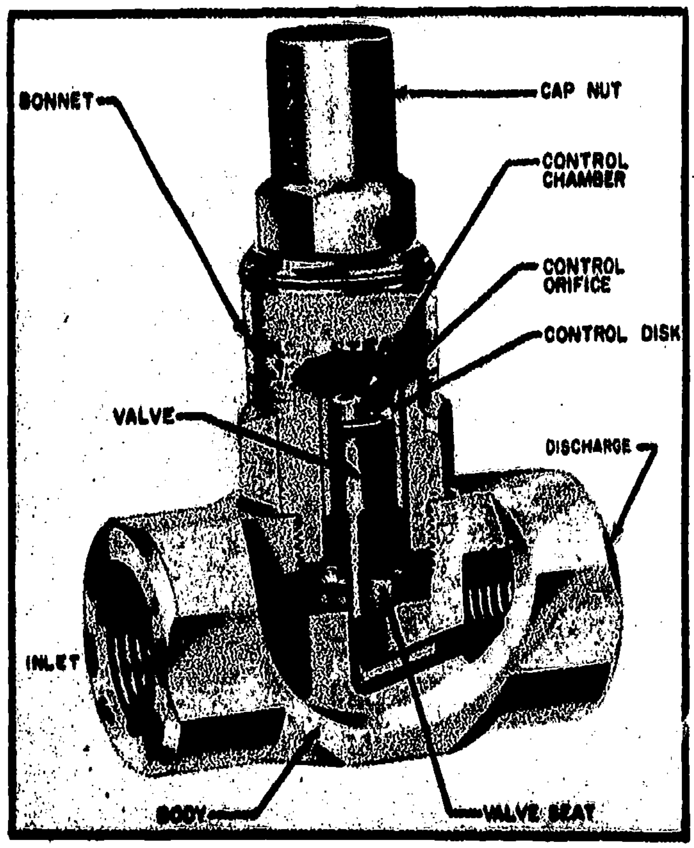
THERMODYNAMIC STEAM TRAP

The thermodynamic (or TD) steam trap, illustrated in figure 15-32, consists of three



11.325(54)EX
Figure 15-29. — Inverted bucket trap.

simple parts: body, cap, and valve head. The valve head is the only moving part of this trap. In operation, condensate pressure raises the disk from the seat, discharging condensate at steam temperature. When steam follows, the high velocity of steam creates a low pressure area under the disk while, at the same time, building up pressure, by recompression, in the chamber above the disk. The pressure in the chamber, acting on the full top area of the disk, exceeds the force of the incoming steam and the low pressure area under the disk. This unbalanced

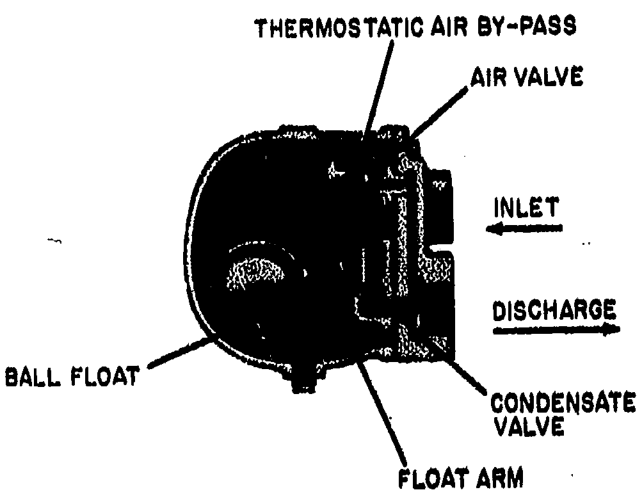


11.325(54)GX
Figure 15-31. — Impulse trap.

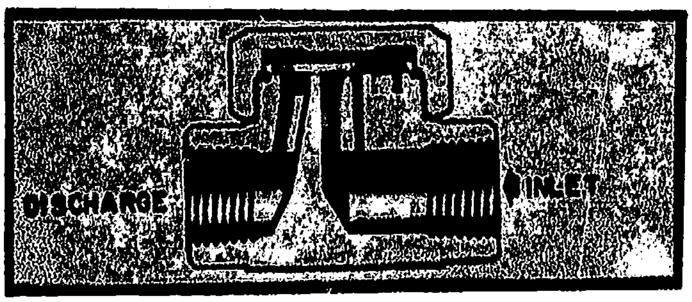
pressure forces the disk down, closing the inlet. As condensation decreases the pressure in the chamber, the disk is raised and the cycle is repeated.

THROTTLING TRAP

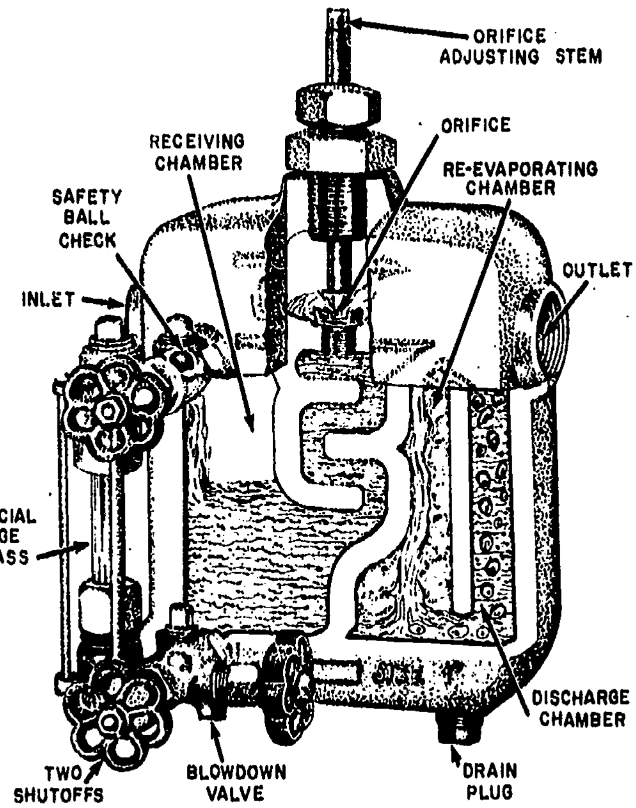
A throttling trap operates on the principle that flow of water through an orifice decreases as its temperature approaches that of the steam used. (See fig. 15-33.) This trap has no moving parts and the rate of flow through it can be adjusted by raising or lowering the stem which fits a tapered V-seat. With the stem properly adjusted, the condensate, which is slightly cooler than the steam, enters the chamber from the line, travels up through the baffle passage, and is discharged through the orifices. If this discharge is at a rate higher than that at which it enters the trap, the level in the inlet chamber falls until it permits a little steam to enter the baffle passage. The steam going through this passage heats the condensate to a temperature approaching that of the steam. As the temperature increases, the amount of water flashing into steam, and



11.326(54)X
Figure 15-30. — Float and thermostatic trap.



11.325(54)AX
Figure 15-32. — Thermodynamic steam trap.



11.325(54)H
Figure 15-33. — Throttling trap.

hence the volume of the steam-water mixture handled by the orifice increases, and reduces the capacity of the orifice. The reduced flow through the orifice permits the level of condensate in the inlet chamber to rise until the hotter water in the baffle passage has been completely discharged and replaced with water that is slightly cooled. The cycle is then repeated. The orifice vents air from the trap; otherwise, steam would be excluded and as a result, the condensate would cool. This condition results in a high flow through the orifice, dropping the water level and permitting the air to enter the baffle passage and to escape.

POINTERS ON OPERATING PROCEDURE

To help ensure trouble-free service of steam traps, proper operating procedures should be carefully followed. Some important factors involving operating procedures are given below.

Steam traps should be operated within the capacity rating and pressure differentials recommended by the manufacturer. Use traps for the correct pressure and temperature. If operating pressures change, it may be necessary to change trap sizes, or internal parts, to fit the new pressure conditions.

Traps should be insulated where heat conservation is a major consideration. Some types of traps, however, which depend on the cooling effect of the condensate for operation should be left bare. Check the manufacturers' instructions regarding insulation.

Where continuity of service is a requirement, a three-valved bypass is usually provided to permit drainage while the trap is being overhauled. Bypasses are also used to speed up the discharge of condensate and air when starting a system. In normal operation, however, the bypass valve should be kept closed to prevent steam wastage.

Check valves, located in the discharge line, are important in parallel installations to prevent the discharge of one trap from backing up into that of another. Also, when condensate from the trap must discharge to a higher elevation, a check valve prevents back flow of condensate.

Inverted bucket traps must be primed for operation by providing a condensate seal in the bottom of the trap. Prime the trap before starting operation by removing the test plug on top of the trap and filling the trap with water. If no test plug is available, the trap can be primed by closing the discharge valve and opening the steam supply valve slowly until the steam is condensed and the trap is filled with condensate.

Blowdown steam traps periodically to rid them of dirt and sediment. Blowdown and clean strainers as required.

When overhauling traps, do not remove thermostatic elements while hot. This may result in expansion beyond the stroke range of the bellows or diaphragm.

Periodically, open the air vents of float traps not provided with thermostatic air vents, to vent out accumulated air.

STEAM TRAP TESTS

Traps can be tested without breaking the installation by using the following methods:

TEST VALVE METHOD. Close the discharge valve and open the test valve. Observe discharge characteristics. Intermittent discharge, dribble, or semicontinuous discharge indicates correct operation. A continuous steam blow indicates loss of prime, defective valve operation, or foreign matter embedded in the valve seat. A continuous condensate flow may indicate that the trap is too small, the amount of condensate abnormally high, or a pressure differential that is too low.

GLOVE TEST METHOD. Grab inlet and outlet pipes simultaneously using a canvas glove on each hand for protection. A slight temperature difference indicates that no condensate is passing.

PYROMETER TEST METHOD. This method is more accurate than the previous one as it uses a surface contact pyrometer to check inlet and outlet temperatures. File a clean spot on both pipes before taking readings.

PYROMETRIC CRAYON TEST METHOD. Temperature indicating crayons can be used when no pyrometer is available. Select crayons of proper temperature ratings and mark the required pipe spots. When the crayon marks melt, the temperature of the test spots corresponds to those of the crayon ratings.

EAR TEST METHOD. Hold one end of a metal rod to the trap body and place the other end in the ear, or, use an engineer's stethoscope. If the trap is operating properly you will hear the regular opening and closing of the valve. If operation is defective, you will hear considerable rattling or the continuous flow of steam.

PROTECTION AGAINST FREEZING

Protect traps from freezing in cold weather. If the steam is shut off during freezing weather, drain the traps and piping of all condensate. Make certain insulation is in good condition. The inverted bucket trap is especially prone to freezing because in normal operation it is half-filled with water.

WATER TANKS

A boiler plant and heating system cannot be operated so the flow of water and the flow of steam are always in balance. The demand for water by the boiler may exceed the rate at which water is being returned from the heating system, or the water may be returning at a rate which is greater than the requirements of the boiler. One or more tanks can be installed to compensate for uneven flows and for differences between the demand and supply of water. These vessels are called surge tanks.

Sudden reductions in pressure may lead to violent steam formation. Flash tanks help eliminate disturbances in the piping system caused by this process. These tanks are usually small and located near the traps where the pressure release occurs.

FUEL OILS

Fuel oil is defined as any liquid product which is burned in a heater or firebox for the generation of heat. The manufacturer of fuel oils is relatively simple. The fuels result from the various distillation processes employed in all petroleum refining. To bring them up to specifications, the normal procedures of filtering and blending are necessary.

Fuel oils may be classified as: (1) residual fuel oil which is either topped crude or viscous cracked residuum: (2) distillate fuel oil which consists of distillate derived directly or indirectly from crude petroleum (chiefly from the gas oil fraction), or (3) blended fuel oil which is a mixture of the first two. The most common blending operation is cutting back the heavier fuel oils by blending with a light product, normally in the diesel fuel range. The information below will help you acquire a basic knowledge of fuel oils. Additional information on the subject of fuel is presented in chapters 13 and 14.

FUEL OIL, BURNER (MILITARY)

Fuel oil is burned in the furnaces of boilers to generate heat which is transferred to water, generating steam which serves to carry the heat energy necessary to produce useful work. This work includes the production of power for lighting, ventilating, heating, cooking, refrigeration, and for operation of various types of electrical equipment.

The military specification for boiler fuel oil provides for two grades: (1) Navy Special which is intended for combatant vessels: and (2) Navy Heavy which is intended for other than combatant vessels. A comparison of the two grades may be made by referring to the Military Specification for Fuel Oil, Boiler. In addition to tests to determine ash, carbon residue, pour point, and thermal stability, Navy Special fuel oil must pass certain qualification tests. Also, Navy Special must be subjected to a compatibility test. This is necessitated by the fact that the Navy obtains its fuels on a worldwide basis and while two fuels might be stable by themselves and offer no problem as to sedimentation or fouling of heater surfaces, a mixture of the two fuels might be harmful.

The compatibility test is done by mixing the Boiler Fuel Oil, Navy Special, under test in a 1 to 1 ratio with approved reference fuels, and then subjecting the mixture to thermal stability tests. It has been found that straight run fuels are compatible; cracked fuels which are in themselves stable are compatible; blends or cracked and straight run fuels may or may not be stable depending upon the properties of each blend. Standard reference fuels have been selected to represent: (1) the cracked type, and (2) the straight run type of fuel.

FUEL OIL, BURNER
(COMMERCIAL)

Burner fuel oil is intended for use in oil-burning equipment for the generation of heat in furnaces for heating buildings, for the generation of steam, or for other purposes. Five grades are established as follows:

1. Grade F.S. No. 1, a volatile distillate oil for use in burners which prepare fuel for burning solely by vaporization.
2. Grade F.S. No. 2, a moderately volatile distillate oil for use in burners which prepare fuel for burning by a combination of vaporization and atomization. This is intended particularly for use in equipment where oil is burned in contact with, or in close proximity to, metal or refractory surfaces that are an integral part of the burner.
3. Grade F.S. No. 4, which is an oil for burner installations not equipped with preheating facilities.
4. Grade F.S. No. 5, which is an oil of medium viscosity, for use in burners with preheaters, requiring an oil of lower viscosity than grade F.S. No. 6.
5. Grade F.S. No. 6, a high viscosity oil for use in burners with preheating facilities adequate for handling oil of high viscosity.

THERMAL VALUE
OF FUEL OILS

The thermal (calorific) value of fuel oil is the amount of heat produced as a result of its complete combustion and is expressed in calories or Btu's (British Thermal Units). A calorie is the amount of heat necessary to raise the temperature of one gram of water one degree Centrigrade. The British Thermal Unit is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. One Btu is equal to 252 calories.

A knowledge of the thermal value of fuel oil is necessary in determining the efficiency of oil-burning equipment, and may also be useful in choosing between oils which are equally satisfactory for a specific purpose.

To determine the thermal value of a fuel oil, a sample of the oil to be tested is placed in a bomb, which, in turn, is placed in a water-jacketed calorimeter. The sample is ignited and the rise in water temperature measured. The gross thermal value is the figure obtained by dividing the temperature rise of the water by the weight of the sample. To determine the net thermal value, certain corrections are made. It should be noted that the net thermal value may be 1,000 Btu's lower than the gross thermal value.

In general, it may be said that the thermal value per unit of weight increases as the API gravity increases. For example, an oil of 10 API gravity may show 18,270 Btu's per pound, while an oil of 20 API gravity may show 18,850 Btu's per pound. However, the reverse is true when the quantities are measured in terms of volume. For example, the 10-gravity oil may show 152,120 Btu's per gallon, and the 20-gravity oil 145,800 Btu's per gallon.

GRAVITY

Specific gravity is the ratio of the weight of a given volume of a substance to the weight of an equal volume of water. Normally, the gravity of petroleum products is expressed in degrees API, in accordance with the API (Americal Petroleum Institute) scale. The relationship of specific gravity to API gravity, expressed as degrees API, is given in the following formula:

$$\text{Specific Gravity} = \frac{141.5}{131.5 + \text{degrees API}}$$

From this formula it can be seen that an oil of 10° API gravity is equal to 1, or the specific gravity of water. All gravity determinations are correlated with a specific temperature and are generally corrected to a standard temperature of 60° F by use of tables.

Either the specific gravity or API gravity of petroleum products must be determined to make volume corrections at different temperatures. Gravity may also be a rough index of whether an oil is naphthenic or paraffinic, but other tests are more indicative of the quality characteristics of the product.

Measurements of both specific gravity and API gravity are made by use of hydrometers. Hydrometers marked according to the API scale are normally used in the petroleum industry. However, if such hydrometers are not available, ordinary hydrometers may be used and conversions made to degrees API by use of the above formula expressed as:

$$\text{Degrees API} = \frac{141.5}{\text{specific gravity}} - 131.5$$

FLASH AND FIRE POINTS

The flash point of a petroleum product is the temperature at which it first gives off sufficient flammable vapor to ignite. The fire point is the temperature at which its vapors will continue to burn. The fire point of any product ranges from 10° to 70° higher than its flash point.

Flash and fire points are used principally to indicate the fire hazards of petroleum products. Knowledge of flash and fire points is particularly important when handling lightly volatile products such as gasoline and solvents.

CLOUD AND POUR POINTS

The cloud point of an oil is the temperature at which its paraffin content, normally held in solution, begins to solidify and separate in tiny crystals, causing the oil to appear cloudy or hazy.

The pour point of an oil is the lowest temperature at which it can be poured.

VISCOSITY

The viscosity of a liquid is a measure of its internal friction, or its resistance to flow. A liquid has high viscosity if it flows sluggishly, like cold molasses; it has low viscosity if it flows freely, like water.

CHAPTER 16

BOILER OPERATION, MAINTENANCE AND REPAIR

As a Utilitiesman, it is your responsibility to operate, maintain and repair boilers. In connection with the operation and maintenance of boilers, you will be required to stand routine watches; keep boiler operating logs; perform operator's maintenance on shore-based boilers; perform preventive maintenance and minor repairs on boilers and associated equipment; complete chemical tests on boiler water and feed water; replace defective boiler tubes; clean watersides and firesides of boilers; and test, adjust, and recalibrate boiler gages and other accessories.

This chapter provides information on some of the methods, procedures, and techniques used to safely operate, maintain, and repair boilers and associated equipment under typical conditions. Additionally, information is included on the procedures to follow when performing boiler and feed water tests. Because of the broad scope of tasks involved in operating and servicing boilers, this chapter does not tell you all you need to know about the given subject. The jobs described in this chapter are typical of those you should be able to perform at the Third or Second Class level of the UT rating. Learning how to accomplish the procedures given in the following sections will help you to acquire the basic foundation on which to develop more advanced skills. Various types, kinds, and models of boilers are used to explain given job procedures. This is an advantage since you may be required to work with different makes and sizes of boilers. While the procedure given in this chapter are typical, you should always follow the manufacturer's instructions for the equipment being used.

BOILER OPERATING LOGS

The main purpose of boiler operating logs is to provide a means of recording continuous data on boiler plant performance. Logs become a source of information needed for making an analysis of the boiler's operation for maintenance and repair purposes. The daily operating log sheets provide the basic information around which maintenance programming is developed. The log is arranged for use over a 24-hour period divided into three 8-hour shifts. Log sheets may vary among different activities, but you should have no difficulty in making log entries if you understand the types of information required. The discussion below will give you an idea of the types of information to be entered in appropriate columns of the log.

Steam Pressure. Steam pressure entries are based on steam gage readings and indicate the boiler's performance.

Steam Flow. Record actual output of the plant in pounds per hour to obtain steam flow. The data from these entries are used to determine the number of boilers to operate for greatest efficiency.

Feedwater Heater Pressure. Feedwater heater pressure indicates if the proper deaerating temperature can be maintained in the heater.

Feedwater Heater Temperature. Feedwater heater temperature shows the effectiveness of the feedwater heater. A drop in steam-supply pressure or insufficient venting may cause low heater temperature.

Feed Pump Pressure. This entry indicates the effectiveness of boiler feed pumps. If the feedwater supply fails, the pressure reading enables the operator to determine if the trouble is in the feed pumps. Pumps are defective if the feed pump pressure reading is below normal.

Last-Pass Draft. This entry indicates the actual draft produced by the stack or the induced draft fan. Ensure that you are familiar with the last-pass draft at various firing rates when the boiler is operating satisfactorily. A decrease in the last-pass draft with other conditions constant indicates leaking baffles. An increase shows that gas passes are becoming clogged.

Percent CO_2 Flue Gas. This value is a measure of relative quantities of air supplied with fuel. It is kept at a value which has been established as most satisfactory for the plant, fuel, firing rate, and other related factors. In plants not equipped with CO_2 recording meters, this value is determined with a hand gas analyzer. With experience, the correct amount of air supplied to a furnace can be determined from draft gages and by observation. In all cases, find values by using a hand gas analyzer.

Flue Gas Temperature. This is an indication of the quantity of heat leaving the boiler with flue gases. This heat represents a direct energy loss in fuel. Abnormally high flue gas temperatures at given boiler firing rates are caused by dirty heating surfaces or leakage of baffles. If the heating surface has a coating of soot, heat which cannot escape is discharged to the stack. Leakage of heat through baffles allows gases to take a shorter path than intended, and reduces the contact of gases with the entire heating surface. Excessive fouling of firesides of boilers increases draft loss while leaking baffles decrease draft loss. Either condition raises the temperature of flue gases above normal.

Fuel. Always determine the quantity of fuel being used as this represents a major operating cost. Fuel oil quantities are determined by use of a measuring stick, in conjunction with tables supplied with a given tank. Some tanks are equipped with gages which indicate the fuel volume.

Outside Temperature. A heating plant load is greatly influenced by outside temperature. Record this temperature for comparison with steam generated and fuel used. These comparative values are useful in determining abnormal fuel consumption and in estimating future requirements.

Makeup Water. Record the quantity of makeup water used, to enable the operator to note an abnormal increase before a dangerous condition develops. Return all possible condensate to the boiler plant in order to save water and chemicals used to treat water.

Water Pressure. Feedwater is most important to safe boiler-plant operation. A record of water pressure indicates whether water is sufficient.

Hot Water Supply Temperature. Record hot water supply temperature. Insufficiently heated water can cause scaling or deposits in a boiler.

Water Softeners. Where softeners are employed, keep a meter record to inform the operator when units must be regenerated. A decrease in the quantity of time used for runs between regeneration indicates either an increase in hardness of incoming water or deterioration of softening material.

Total and Averages. Space is provided for recording the total and average quantities per shift.

Steam Flow. Steam-flow-meter integrator reading at the start of a shift, subtracted from the reading at the end of a shift, and multiplied by the meter constant gives the quantity of steam generated. Dividing steam generated by fuel burned (gallons of oil) yields a quantity which indicates economy obtained. If a plant does not have a steam-flow meter, pumps may be calibrated for flow and a record kept of their operating time, or condensate and makeup water may be metered.

Boiler Feed Pumps in Service. A record of boiler feed pumps in service makes it possible to determine operating hours and to ensure that various pumps are used for equal lengths of service.

Phosphate, Caustic Soda, and Tannin Added. A record of phosphate, caustic soda, and tannin used is valuable in keeping the correct boiler-water analysis and in determining total chemicals used.

Remarks. The remarks column is used to record various types of information for which space is not provided elsewhere on the log sheet. List equipment to be checked daily. Note all irregularities which are found in connection with all inspections. List the date when boilers are drained and washed out thoroughly at intervals determined by local water conditions. Indicate the condition of internal cleanliness.

Other Personnel. Names of personnel responsible for specified tasks and data must be entered on the log sheet if required.

BOILER OPERATION

The operation of a boiler consists of six major phases: (1) prewatch assumption checks, (2) preoperating checks, (3) lining-up systems, (4) operating procedures, (5) operating checks, and (6) securing procedures.

PREWATCH ASSUMPTION CHECKS

The PREWATCH ASSUMPTION CHECKS are often neglected by boiler watchstanders. Before you assume the responsibility of a boiler watch stander, you are required to complete specified checking procedures to ensure that the equipment in service is in sound operating condition and is functioning satisfactorily. Normally, when the watch is relieved, the watchstander coming on duty inspects the instrument readings and charts, visually inspects all equipment, and exchanges information with offgoing watchstanders. Oncoming watchstanders should complete the following inspections and tests before assuming duty:

1. Visually inspect setting and casing.
2. Observe furnace and firing conditions.
3. Inspect charts to determine apparent performance of equipment, controls, etc.
4. Inspect fans, dampers, damper drives, and other driven auxiliaries.
5. Test water columns and gage glasses.
6. Test alarm units.
7. Obtain information regarding the boiler's operating condition and ask the watchstanders on duty if any unusual events or trouble occurred during their watch period.

Immediately after accepting the operational responsibility, a complete inspection of all auxiliary equipment should be made, as follows:

1. Inspect all electric motor drives for evidence of abnormal temperature, condition of bearings, etc.
2. Inspect the fan and pump bearings for evidence of overheating and adequacy of lubrication.
3. Visually inspect the boiler and all associated equipment, being careful to listen for unusual sounds, friction, vibration, and other abnormal conditions.
4. Inspect the burners, fuel supply, pilot systems, and other fuel supply components.
5. Review the log sheets to obtain information on past operating conditions and unusual events that occurred.

PREOPERATING CHECKS

The PREOPERATING CHECKS should be completed before lining-up and lighting off a boiler. These checks are performed to ensure that the plant and associated equipment are in a safe and efficient operable condition. The major preoperating procedures applicable to boilers in general are:

1. Inspect boiler room or area for safety and fire hazards.
   a. Remove rags, paint cans, oil spots on floor, and so on.
   b. Remove tools and equipment from area that may cause injury.
2. Furnace and gas passages
   a. Must be clean and clear
   b. All doors must fit tight
   c. Must be in good repair
   d. Make sure there is no oil or tools in combustion chamber
   e. Must be purged
3. All valves must be inspected for:
   a. Good operating condition
   b. Bent stems
   c. Missing or broken handwheels
4. Piping
   a. Inspect all piping for leaks
   b. Check for proper supports
5. Electrical system should be checked for:
   a. Oil-soaked or frayed wire insulation
   b. Damaged or loose conduit
   c. Improperly secured control boxes
6. Guards: Make sure guards for moving parts are tight and in proper position
7. Water gage glass
   a. Must be well lighted
   b. Must not be stained
   c. Must not leak at connection
   d. Should have a guard in place
8. Dampers
   a. Must not stick
   b. Must be in good working order
   c. Must be open before lighting off
9. Air cock
   a. Open to adjust water level on cold boiler
   b. Open to vent boiler of air, if boiler is cold
10. Pressure gage
    a. Must be correct and clean
    b. Must be well lighted
    c. Cock in line must be open
11. Steam line drains: open if line is cold
12. Protective controls
    a. Check low water cut-off
    b. Flame failure
       (1) Test frequently, with burner operating
       (2) Frequency depends upon base or battalion regulations
13. Auxiliary equipment
    a. Ensure that the following major items in a safe and operable condition and lubricated:
       (1) Boiler feed pumps
       (2) Oil pumps
       (3) Draft fans
       (4) Feed tank
       (5) Feed water heater

Before operating GAS-FIRED BOILERS you should check the following items in addition to those listed above:

1 The pilot and main gas cock for smooth operation
2. All copper tubing for restriction due to kinks and flat spots
3. Air shutters
   a. Must operate freely
   b. Linkage must not have excessive amount of lost motion
4. Burner and main gas valve must be firmly supported
5. Be sure boiler room has no free gas. If gas is present, ventilate and test piping with soap solution.

Before operating OIL-FIRED BOILERS you should check the following items.

1. Strainers
   a. Inspect and clean
   b. Renew if wire mesh is defective
2. Burners
   a. Must be clean
   b. Nozzle must be clean
   c. Inspect and set electrodes
   d. Fittings must not leak
   e. Operation of burner safety switch
3. Oil system
   a. Inspect for leaks: make necessary repairs if leaks are present

LINING-UP SYSTEMS

After you have completed the preoperating checks, your next job is to line up the boiler systems. The procedures used in lining up boiler systems (fuel, water, steam and electrical) will vary with different types and kinds of boilers. Always follow the manufacturer's instructions for the boiler being used.

Before lining up a boiler, the following basic tasks should be completed:

1. Fuel oil
   a. Measure with stick or gage
   b. See that proper valves are open
   c. Remove any excess accumulation of water in tank
2. Gas
   a. Check pressure
   b. Check for leaks
3. Gas-fired unit
   a. Check and regulate water level, line up feed system
   b. Examine burner, control valves, and safety out-outs for proper working condition before lighting off
   c. Purge air out of gas lines by external vents before lighting off
   d. Check draft devices and purge combustion chamber
   e. Light pilot and set flame
   f. Open main gas cock
   g. Close burner control switches which will ignite burner
   h. Maintain fuel-air ratio to maintain complete combustion
4. Oil-fired unit
   a. Check and regulate water level. Line up feed-water system. Check operation of feed pump
   b. Line up fuel oil system
   c. Purge combustion chamber
   d. Close burner control switch; if automatic, burner should light off
   e. Should ignition fail, furnace must be purged before second attempt
   f. Do not allow oil to impinge on brickwork or part of boiler
   g. Maintain proper air-fuel ratio

The following basic lighting-off procedures are applicable, in general, to most boilers:

1. Close the following valves
   a. All blowdown valves
   b. Boiler drains
   c. Chemical feed valves
   d. Boiler non-return
   e. Main-steam-stop
   f. Soot blower header (steam system)
   g. All burner fuel valves
   h. All soot blowers
   i. Water column drains
   j. Feed-water regulator drains
   k. Auxiliary valves, as necessary
2. Open the following valves:
   a. Vent valves on boiler drums and superheaters
   b. Superheater drain valves
   c. Recirculating line valves in economizer, if so fitted
   d. Feed-water stop and check
   e. Drum steam gage connection
   f. Water column gage connections
   g. Water column gage glass valves
   h. Auxiliary valves, as necessary

3. Start filling the boiler with properly treated water at a temperature relatively close to the temperature of the pressure parts. The temperature difference should not be greater than 50° F to avoid severe temperature stresses. Fill the boiler to a level just below the middle of the glass on the water column.

4. Close the induced draft fan dampers (or other flue gas control dampers).

5. Start the induced draft fan.

6. Close the forced draft fan dampers (or other air control dampers).

7. Start the forced draft fan.

8. Start the air heater rotor, if a regenerative type air heater is installed.

9. Light-off the boiler in accordance with the manufacturer's instructions and maintain a firing rate so that the water temperature in the boiler is raised at the rate of 100° F per hour until operating pressure is reached. On new boilers, expansion movement should be checked to see that no binding or interference occurs.

10. When burning oil, prevent incomplete combustion in the furnace; any unburned oil will be deposited on the cooler surfaces in the back of the unit, such as the economizer and air heater. This creates a potentially dangerous situation.

11. When the steam drum reaches approximately 25 psig, close the vent valves on the boiler drum. Check the steam pressure gage at this time to be sure it is registering.

12. Ease up on the stem of the main steam stop valve to prevent any serious expansion stresses. If there is no steam on either side of the main steam stop valve, gently lift and reseat it to make sure that it is not stuck. Open the drain valve on the boiler side of the main stop valve.

13. Observe the water level carefully, to ensure that no water is carried over into the superheater. Maintain a normal water level in the drum by blowing down or feeding water as may be required.

14. Operate the vent and drain valves in the superheater headers and economizer by following the manufacturer's instructions. In general, drain valves in the superheater inlet header are closed first, followed by the drains in the superheater outlet header. In any case, the superheater outlet header drain and vent valves must not be completely closed until an adequate steam flow through the boiler outlet valve is assured.

15. Check for leaking gasket joints. If a leaking gasket is discovered, shut down the boiler and tighten the joints.

16. If the gasket still leaks, drop the pressure again, replace the gasket and repeat the lighting-off sequence.

Before cutting-in the boiler, proceed as follows:

1. Open all drain valves between the boiler and the header, especially the drains between the two stop valves.

2. Warm up the steam line between the boiler and the header by backfeed through the drip line or by means of the bypass valve.

3. When the steam line is thoroughly heated and at header pressure, open the header valve.

4. When the boiler pressure almost reaches line pressure, open the bypass line around the main steam stop valve to equalize pressures and temperatures in the piping; then slowly open the main steam stop valve. As the boiler reaches line pressure and is actually steaming, the non-return valve stem is slowly raised to the full open position.

5. After the boiler is on the line, close all superheater drains.

6. Inspect the entire boiler, and close any drain valves that are not discharging condensate.

7. Close the economizer recirculating valve, when an adequate continuous feed-water flow is established.

8. Close the drain valve at the non-return valve.

9. Close the bypass valve around the non-return valve.

10. When operating a boiler having a pendant (nondrainable) superheater, the operation will be slightly different. Superheaters of this type will trap condensate in the loops which must be boiled off before the firing rate can be increased and the steam flow is started.

11. It is very important to maintain a constant firing rate. The strength of thick steam drums may be impaired by excessive temperature differentials between the top and the bottom of the drum, if the proper firing rate is not maintained. Tubes may start leaking at rolled seats and the superheater tubes may overheat.

12. On boilers generating saturated steam, it is necessary to follow the manufacturer's specified firing rate and follow the above instructions for removing air and condensate.

OPERATING PROCEDURES

Success in operating boilers depends largely upon the operator being well informed and constantly vigilant. No fixed set of rules can be established that will be adequate for all conditions. Consequently, the operator must see and interpret all prevailing operating conditions and, if necessary, take action to control, modify, or correct them. To be able to do this, the operator must be thoroughly familiar with the characteristics and standard operating procedures for the boiler for which he is responsible. This section will acquaint you with some of the basic operating procedures which generally may apply to most, if not all, boilers you will be assigned to operate. For specific operating instructions, consult the manufacturer's manual for the boiler concerned.

Normal Operation

During normal operation of boilers, the operators have two major responsibilities. The first is to see that proper water level is carried at all times. If the water level is too low, tubes may overheat, blister and rupture. If the water level is too high, carryover of water to superheater tubes may occur, causing damage to the superheater elements and to the turbine. Check the water gage frequently to be certain it is reading correctly and that the proper water level is being maintained. The second major responsibility is to prevent loss of ignition when burning fuel is in suspension, such as gas or oil. Maintain safe and efficient combustion conditions in the furnace and the correct fuel-air flow ratios.

Blowdown

Establish definite intervals for blowing down the boiler, depending on the type of operation and the chemical analysis of the water from the boiler. During regular operation, never blowdown economizers or water-cooled furnace walls.

Blowdown valves on this type of equipment are provided to serve only as drain valves. When using low point drains or blowdown valves, boilers should be blowndown at reduced or moderate rates of steaming. Where the water glass is not in full view of the operator blowing down a boiler, another operator should be temporarily assigned to observe the water glass and signal the operator manipulating the valves. For control of water conditions when working, it is wise to use a continuous blowdown to maintain the proper concentration at all times, and to prevent blowing down large quantities of water while the boiler is operating at a high capacity.

Boiler Make-Up

Use only properly treated water for make-up purposes, and maintain the boiler water conditions as specified in the water treatment instructions. Make an accurate water analysis at specified intervals. Carefully control the blowdown and the addition of treatment chemicals to meet the manufacturer's specifications.

Soot Removal

Remove soot from hoppers and pits at definitely established intervals, as necessary.

Instrument Readings

Establish definite intervals for observing and recording the readings on all important instruments and controls. Be sure you obtain accurate readings and see that the readings are recorded properly on the log sheet or other required record.

OPERATING CHECKS

To help ensure efficient operation of the boiler, see that the following operating checks are carefully made:

1. Water level
   a. Check frequently as water expands during heating up period
2. Main steam stop by-pass (if installed)
   a. Open if boiler is to be cut in on cold line
   b. Main stop can be opened if no other boiler is on same steam line
3. Air cock
   a. Close after steam has formed and has blown all air from boiler
4. Steam pressure
   a. Raise slowly—usually 1/2 to 2 1/2 hours; depends upon type, size and condition of boiler
   b. Temperature of water should be raised at a rate of 100° F per hr.
5. Safety valves
   a. Manually lift when pressure is at least 75% of valve setting

b. Make sure valves reseat properly; if valves fail to reseat properly, lift second time

6. Cutting boiler in
   a. If closed, open main steam stop valve slowly, to:
      (1) Avoid thermal shock
      (2) Avoid water hammer
7. Boiler feed water
   a. Commence feeding boiler as needed
   b. Probably will be automatically controlled
8. Firing
   a. Gas
      (1) Maintain ignition
      (2) There should be no soot formation
      (3) Maintain proper air-fuel ratio
   b. Oil
      (1) Maintain ignition
      (2) Observe flame and adjust dampers. Check accuracy by flue-gas analysis
9. Water level
   a. The first duty when taking over the water is to blow down gage glass and water column. Note: Observe the promptness of the return of water in glass.
   b. Keep at proper level
   c. Don't depend entirely upon automatic regulators
   d. At frequent intervals compare readings of different methods to determine true water level; use try cocks.
10. Boiler blowdown
   a. Rids boilers of mud, scale, rust, and other suspended impurities in the water
   b. Open quick-opening valve fire — slow-opening second. Close in reverse order.
   c. Frequency and amount of blowdown depends on water tests
   d. Keep eye on gage glass
11. Efficient operation
   a. Flue gas temperature
      (1) Keep low
      (2) Should be about 150 degrees higher than temperature of steam being generated
   b. Flue gas analysis
      (1) Take periodically
      (2) Maintain proper CO_2 level for fuel used
   c. Flame
      (1) Long and lazy
      (2) Must not enter tubes
      (3) Not dark and smoky
      (4) Have light brown haze from stack, except gas
      (5) When fuel is oil, have yellow flame with dark or almost smoky tips
   d. Draft
      (1) Usually 0.03 - 0.06 inch of water
      (2) Check manufacturer's recommendations
      (3) Extra is needed when stack and refractory are cold
   e. Make up feed
      (1) Maintain low rate
      (2) Repair leaky steam and return lines
      (3) Avoid excessive boiler blowdown
   f. Insulation
      (1) Keep boiler and lines well insulated
   g. Feed Water
      (1) Maintain proper feed water temperature
   h. Water treatment
      (1) Carry out prescribed treatment of boiler water

SECURING THE BOILER

The recommended procedures for securing boilers are as follows:

1. Reduce the load on the boiler slowly, cutting out the fuel supply by proper operation of the fuel burning equipment.

2. Maintain the normal water level.

3. When the boiler load is reduced to approximately 20% of rating, change the combustion control and the feed-water control to manual operation.

4. Before securing the final fuel burner, open the drain valves at the steam and non-return valve and the drain valve on the superheater outlet header. Be sure the by-pass valve around the non-return valve is closed.

5. Secure the final fuel burner when the load has been reduced sufficiently.

6. Continue operating the draft fans until the boiler and the furnace have been completely purged.

7. Shut down the draft fans.

8. Close the dampers, including the air heater and superheater bypass dampers, when provided.

9. Follow the manufacturer's instructions for the rate of cooling the boiler. A thermal strain may occur if the change is too fast.

10. When the boiler pressure has started to drop, close the steam stop and non-return valve.

11. When the boiler no longer requires any feed and the non-return valve is closed, open the valve in the recirculating connection of the economizer, if provided.

12. Let the boiler pressure drop by relieving steam through the superheater drain valve and the drain valve at the non-return valve. If the boiler is losing pressure at a rate faster than specified by the manufacturer, throttle the drain valves as necessary to obtain the proper rate. Do not close the valves completely.

13. When the drum pressure drops to 25 psig, open the drum vent valves.

14. If a regenerative type air heater is used, the rotor may be stopped when the boiler exit gas temperature is reduced to 200° F.

15. The boiler can be emptied when the temperature of the water in the boiler is below 200° F. Before sending a man into any part of the boiler, close and properly tag all controls, valves and drains or blowdown valves connected with similar parts of other units under pressure at the time. This will prevent any steam or hot water from entering the unit. The tags are to be removed only by an authorized person and must remain in place until all personnel have completed their work. Ventilate the boiler thoroughly and station a man outside. Inside, use only low-voltage portable lamps provided with suitable insulation and guards. Even 110 volts can be lethal under the conduction conditions found inside a boiler. All portable electrical equipment should be grounded and electric extension cords should be well-insulated, designed to withstand rough usage, and maintained in good condition.

BOILER EMERGENCIES

Typical emergency situations encountered in connection with the operation of boilers are: (1) low water, (2) high water, (3) serious tube failure making it impossible to maintain water level, (4) flareback caused by an explosion within the combustion chamber, (5) minor tube failure indicated by trouble in maintaining water level under normal steam demand, and (6) broken gage glass on water column. Table 6-1 gives you the safe procedures to follow when these boiler emergencies occur.

CLEANING BOILER FIRESIDES

Boiler heat transfer surfaces must be kept clean to provide for safe and excellent boiler operation. Excessive fireside deposits of soot, scale, and slag cause the following conditions:

Reduced boiler efficiency.
Corrosion failure of tubes and parts.
Reduced heat transfer rates and boiler capacity.
Blocking of gas passages with resultant high draft loss and excessive fan power consumption.
Fire hazards.

Methods to clean boiler firesides and prevent excessive deposits of soot, slag, and scale include wire brush and scraper cleaning, hot-water washing, wet-steam lancing, and sweating.

WIRE BRUSH AND SCRAPER CLEANING

When an excessive amount of soot is deposited and the passages become plugged, hand lancing, scraping, and brushing are generally employed. Special tools required for reaching between the lanes of tubes may be made from flat bars, sheet metal strips cut with a saw-toothed edge, rods and similar equipment. Some boilers have different sizes of tubes, so you will need various sizes of brushes and scrapers to clean the boiler tubes. The brushes or scrapers are fastened to along handle, usually a piece of pipe, inserted and pushed through the tubes.

HOT-WATER WASHING

This method of cleaning boiler firesides is often used to clean superheaters, economizers, and other sections of the steam generator which are difficult or impossible to reach by brushing or scraping. The water may be applied with hand lances and/or boiler soot blowers. It is necessary to thoroughly dry out the boiler setting immediately after water washing to minimize damage to the refractory and other parts of the setting. Observe the following safety precautions when washing boiler firesides:

1. Wet the boiler refractory and insulation as little as possible.
2. Be sure that sufficient fresh water is available to complete the washing.
3. Protect electrical equipment around or under the boiler from water damage.
4. Install canvas shields or gutters where possible to reduce wetting of refractories.
5. Provide all necessary instructions, gloves, goggles, protective clothing, and other equipment so that workers will not be scalded.

Table 16-1.—Boiler Emergencies

TASKS	KEY POINTS
EMERGENCY ONE: LOW WATER CONDITION INDICATED BY NO WATER LEVEL IN THE GAGE GLASS. Secure the boiler, Secure electrical switches, steam stop and feed stop. Prove water level by opening try cocks. Cool the boiler slowly until the water temperature is 200° F. Secure all sources of draft. Check controls. Find out the cause for low water level. Correct the trouble. After correction has been made, add water to obtain the correct water level.	DON'T ADD WATER TO THE BOILER to raise water level in the gage glass column. STAY AWAY from discharge. DON'T FORCE COOL.
EMERGENCY TWO: HIGH WATER CONDITION INDICATED BY GAGE GLASS FULL OF WATER. Prove water level by opening the try cocks. Blowdown boiler by opening blowdown valves. Find out the cause of high water condition. Check feed pump controls. Correct the trouble. Secure the boiler if pump controls operate improperly.	STAY AWAY from discharge. Check blowdown pit. Watch the gage glass until normal level is reached. If control operates properly, continue to operate the boiler.
EMERGENCY THREE: SERIOUS TUBE FAILURE MAKING IT IMPOSSIBLE TO MAINTAIN WATER LEVEL. Secure the boiler by securing the electrical, steam, and fired systems. Add water to the boiler until the ruptured tube level is reached and the boiler is cooled to a temperature of 200° F. Open the boiler to replace the tube.	For large boilers: Water should be fed to boiler until properly cooled. Mark the gage glass if within its range. Observe level by whatever means available.
EMERGENCY FOUR: FLAREBACK CAUSED BY AN EXPLOSION WITHIN THE COMBUSTION CHAMBER. Secure the boiler. Find out the cause of flare-back and correct the trouble. Check for sufficient fuel and any type of fuel contamination. Check the burner.	Ensure that a slug of water did not interrupt flame with a refire before prepurge.
EMERGENCY FIVE: MINOR TUBE FAILURE INDICATED BY TROUBLE MAINTAINING WATER LEVEL UNDER NORMAL STEAM DEMAND. Secure the boiler if it is possible to remove it from the line for sufficient time to make necessary repairs. Secure electric switches. Open steam stop and feed stop if additional water is not needed to protect remaining tubes.	If unable to secure due to steaming requirements, and you can maintain water level, continue to operate. If unable to maintain water level and/or supply, secure the boiler.
EMERGENCY SIX: BROKEN GAGE GLASS ON WATER COLUMN. Secure top and bottom valves immediately. Use chains or whatever method available to prevent injury to personnel. Replace the gage glass.	Boiler may be kept on the line, if necessary. Check the boiler water level by using try cocks.

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6. Provide a compressed-air lance to loosen scale following water washing.

7. Provide adequate equipment to heat and pump the hot water. The water should be heated to approximately 150° F. Water which exceeds this temperature cannot be handled safely and efficiently; cold water does not clean satisfactorily. A water pressure of 200 to 250 psig should be provided at the cleaning lances or soot blowers. The water jets must penetrate the tube banks and impinge with sufficient force to break up the slag accumulations.

8. Start the water washing at the top of the unit and work down.

9. The unit must be dried out immediately after washing.

WET-STEAM LANCING

This method is similar to the hot water method except that wet steam is used instead of hot water. The steam should be wet and at a pressure of 70 to 150 psig. The unit must be dried out immediately after lancing.

SWEATING

Fireside slag can be removed from convection type superheaters by forming a sweat on the outside of the tubes. Cold water is circulated through the tubes and moisture from the air condenses on the tubes producing the sweat. The hard slag is changed into mud by the sweat, and the mud can be blown off by an air or steam lance. A large tank filled with water and ice can be used as the cold-water source. Steam can be blown into the area around the tubes during the cold-water circulating period to provide adequate moisture in the air.

CLEANING PROCEDURE

The procedure for cleaning boiler firesides is as follows:

1. Remove the boiler from service and allow it to cool. Make sure the boiler is cool enough for a person to enter. Someone must be standing by whenever any person is in the boiler. DO NOT force cool the boiler with draft fans or by adding cold water.

2. Disconnect fuel line openings. Secure all valves, and chain, lock and tag all fuel lines to the burner and install pipe caps.

3. Disconnect electrical wiring. Secure and tag the electrical power to the boiler at the main panel. Remove all fuses from the main electrical panel if practical. Disconnect the burner conduit and wiring. All electrical wires should be marked and tagged to ensure proper installation when rewiring and connecting the burner for operation. Tape the loose ends of all wires to prevent possible electric shock.

4. Open the boiler access doors by loosening all nuts and dogs and swing the door open. Use a wrench of proper size and be careful not to damage refractory door lining.

5. Remove the burner from the boiler openings. Follow the manufacturer's instructions for specified burners. Locate the burner out of the work area, and cover it with canvas or rags to prevent damage and contamination. Protect electric equipment, controls, gages, and other fittings. Wrap this equipment with plastic, rags or other suitable protective coverings. Remember, soot and loose carbon particles must be kept out of burner moving parts at any cost. They could cause the burner to malfunction.

6. Provide all spaces with free air circulation by opening doors and windows, or providing fresh air by mechanical means. Make sure you can breathe easily and comfortably. An assistant should be stationed outside the opening and be ready at all times to lend a hand tending lines, tools, or being of service in case of mishap. Clean lenses as may be required. Remove all materials and equipment that interfere with work or create dangerous obstacles. Be sure all electrical powered equipment is grounded to prevent any accident.

7. Cover the floor area around tube ends with drop cloths to catch soot. Position vacuum cleaner hose at the tube being cleaned to ensure ease of soot removal. Be careful of brushes coming through tube ends. Keep soot from contacting wet areas because soot and water form carbonic acid.

8. Remove tube baffles where possible and pass a hand lance or rotating power cleaner brush through each tube slowly and carefully, to ensure that no damage will occur to personnel or equipment. Remember, the brush must pass all the way through the tube without stopping to prevent binding. Keep flexdrive straight and wear suitable gloves for protection from revolving brushes.

9. Inspect tube surfaces for satisfactory condition before continuing to the next tube. Use a drop cord or flashlight for viewing through the entire length of tube. Wire brush all tube baffles either by hand or power. Remove baffles when possible, or clean in place with a wire brush.

10. Apply a light coat of mineral oil to all cleaned surfaces. To do this, fix an oil-soaked rag to the end of a brush or rod long enough to extend through the tubes and thoroughly swab each surface, including baffles. Mineral oil is the only lubricant that will prevent rusting and also burn off freely without leaving a carbon deposit.

11. Clean all flat surfaces by brushing with hand or power tools. Make sure that powered equipment is grounded.

12. Use an industrial vacuum cleaner to remove loose soot.

CLEANING BOILER WATERSIDES

Any waterside deposit interferes with heat transfer and thus causes overheating of the boiler metal. Where a waterside deposit exists, the tube cannot transfer the heat as rapidly as it receives it. What happens? The tube metal is overheated to such an extent that it becomes plastic and blows out, under boiler pressure, into a bubble or blister.

The term WATERSIDE DEPOSITS is used to include sludge, oil, scale, corrosion deposits, and high-temperature oxide. With the possible exception of oil, these deposits are not usually soluble enough to be removed by washing or boiling out the boiler.

The term WATERSIDE CORROSION is used to include both localized pitting and general corrosion. Most, if not all, waterside corrosion is probably electrochemical in nature. There are always some slight variations (both chemical and physical) in the surface of any boiler metal. These small chemical and physical variations in the metal surface cause slight differences in electric potential between one area of a tube and another area. Some areas are ANODES (positive terminals). Iron from the boiler tube tends to go into solution more rapidly in the anode areas than at other points on the boiler tube.

This electrolytic action cannot be completely prevented in any boiler. However, it can be kept to a minimum by maintaining the boiler water at the proper alkalinity and by keeping the dissolved oxygen content of the boiler water as low as possible.

The watersides of naval boilers may be cleaned in two ways: (1) mechanically, by thorough wire-brushing of all drums, headers, and tubes, and (2) chemically, by circulating chemical cleaning solutions through the boiler.

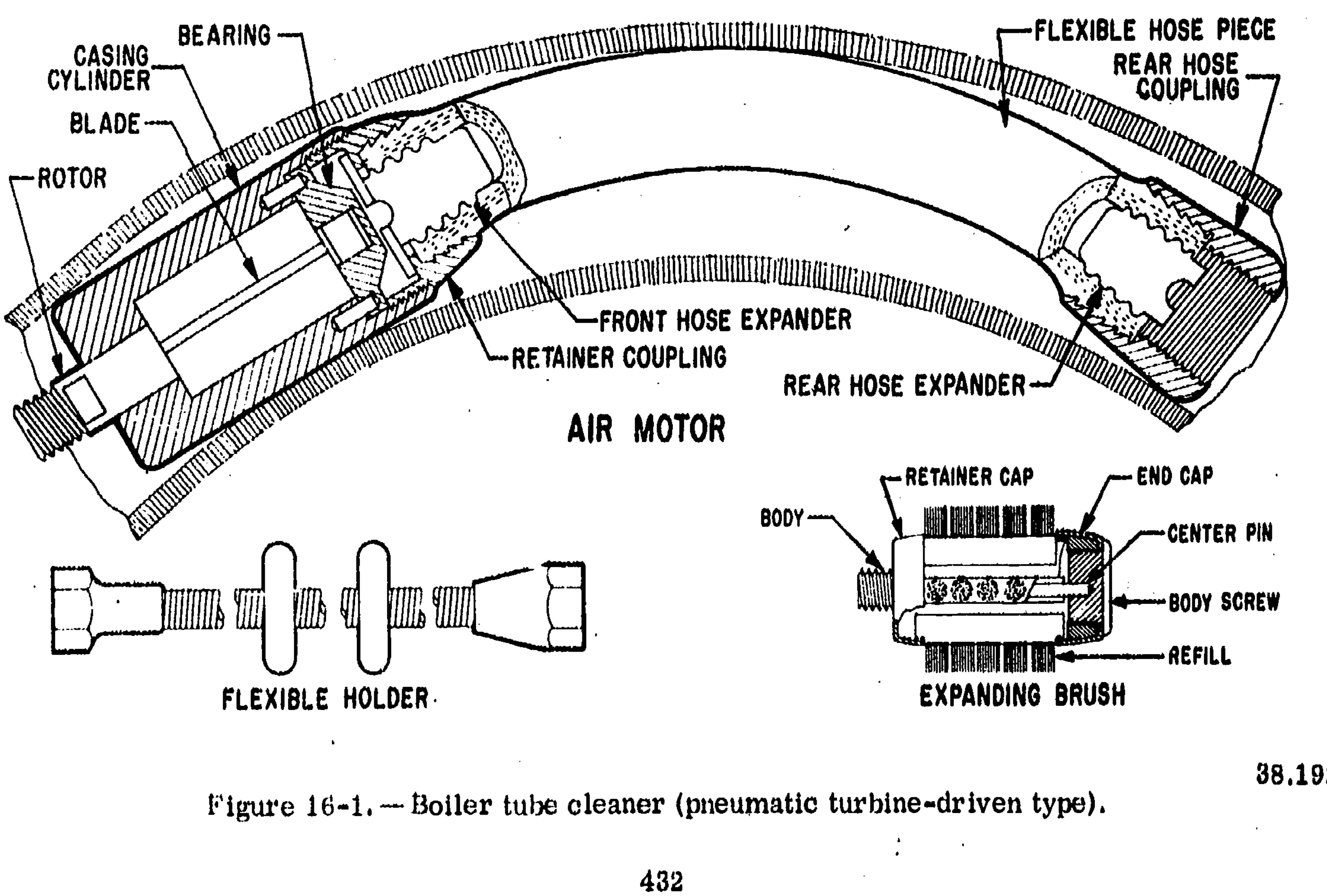

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Figure 16-1. — Boiler tube cleaner (pneumatic turbine-driven type).

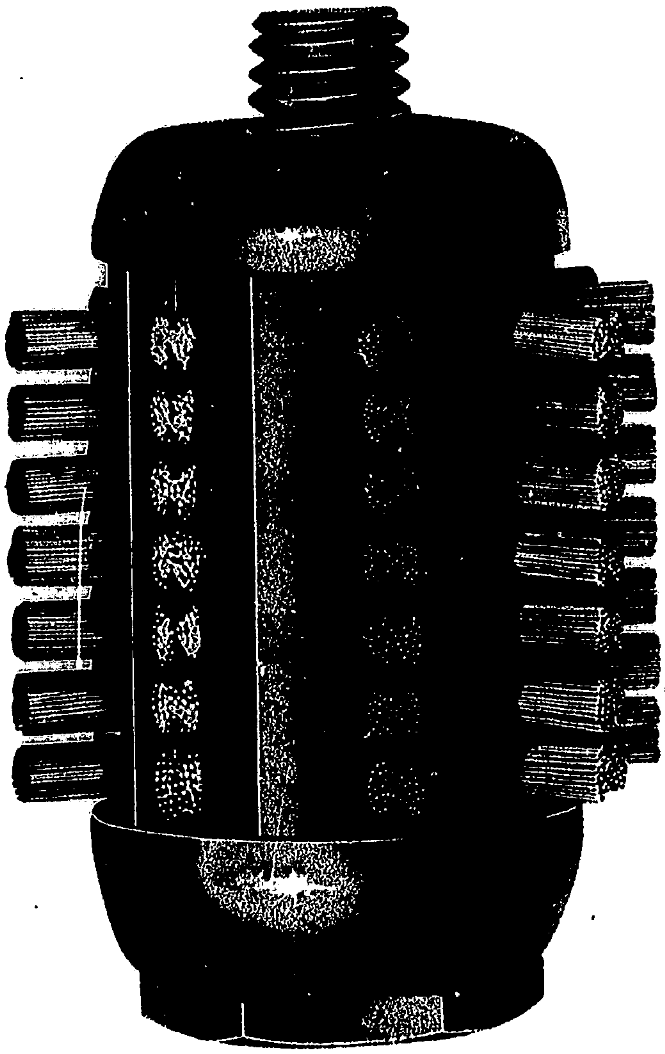

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Figure 16-2. — Wire bristle brush for cleaning generating tubes.

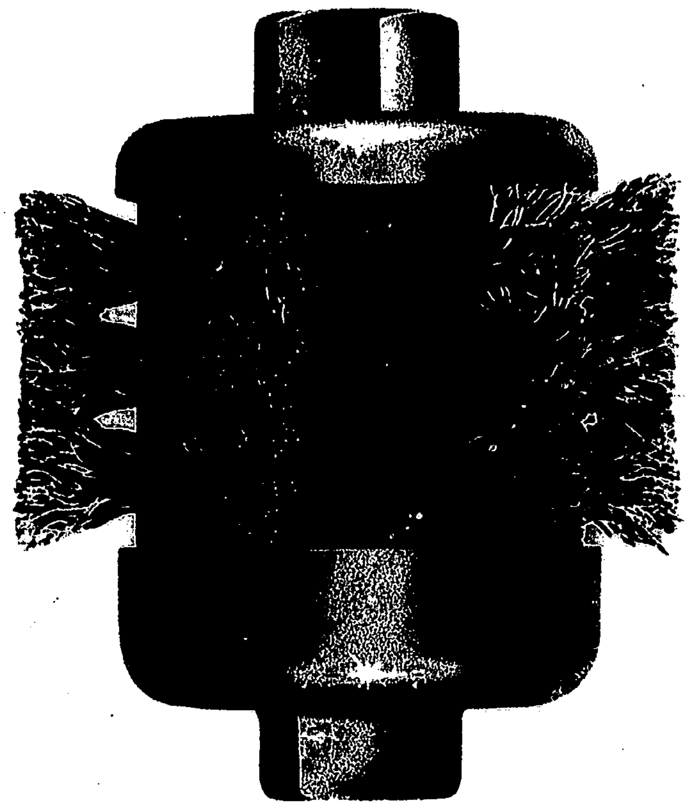

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Figure 16-3. — Wire bristle brush for cleaning large tubes.

MECHANICAL CLEANING

Before mechanical cleaning of watersides is begun, the internal fittings must be removed from the steam drum. The fittings (particularly the steam separators and apron plates) must be marked or otherwise identified as to position in the steam drum to ensure their correct re-installation. All internal fittings must be wire-brushed and cleaned before they are reinstalled.

Cleaning the watersides of the generating tubes will require a special tube cleaner. There are several types available, but perhaps one of the most common is the pneumatic turbine-driven tube cleaner shown in figure 16-1. This type of cleaner consists of a flexible air hose, an air-driven motor, a flexible brush holder, and an expanding wire bristle brush. The turbine-driven motor consists of little more than a set of turbine blades which are made to revolve when compressed air is admitted through the airhose. The turbine-driven motor, in turn, drives the wire brush. There are several sizes of brushes available (see figs. 16-2 and 16-3). Figure 16-4 shows a brush refill for the type brush illustrated in figure 16-2.

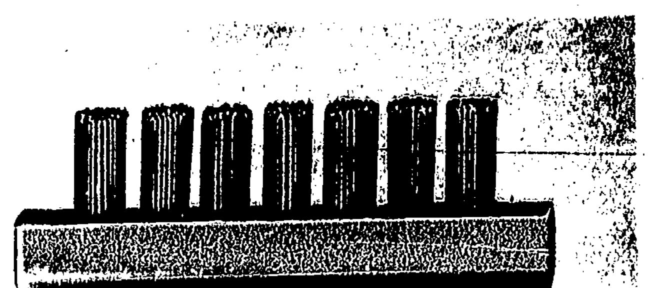

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Figure 16-4. — Brush refill.

Before you start cleaning tubes, be sure that adequate ventilation and lighting have been arranged. A man should also be stationed outside the drum whose only duty is to act as tender and to assist the man or men who are working in the drum. In addition, ensure that all needed tools are available and in good condition. Keep a written checkoff list of all tools and equipment taken into the watersides and be sure that the same tools and equipment are removed. There have been many tube failures immediately after a cleaning job, as a result of tools or rags being left in the boiler.

With the air shut off, insert the tube cleaner in the tube until the brush is about even with the far end of the tube. Wrap friction tape, a rag, or some other marking material around the hose to indicate how far the tube cleaner can be inserted without having the brush protrude beyond the far end of the tube. Then remove the cleaner from the tube. Remember that the tubes in each row are the same length, but that the tube length varies from row to row. Therefore, separate markings will have to be made on the hose for each row of tubes.

After the hose has been marked, insert the brush in the tube and turn on the air to start the brush rotating. Pass the brush SLOWLY along the length of the tube until the identifying mark has been reached. Then slowly draw the brush back, withdrawing the cleaner from the tube. Proceed in the same way with the rest of the tubes in the row. It is not necessary to shut off air to the tube cleaner each time the cleaner is withdrawn from the tube. However, be sure to steady the brush assembly with your hand to keep the cleaner from whipping. Allowing the brush to whip at either end of the tube is the most common cause of broken tubes.

Establish a new mark for the next row and proceed with the cleaning. Make as many passes as necessary through each tube to ensure adequate cleaning. Be careful not to stop the tube cleaner in any one place in the tube, as the continued rotation of the brush in one place might damage the tube. Be careful, also, to see that the brush and the flexible shaft do not protrude from the other end of the tube, as this would probably result in a broken shaft.

Tube cleaning is most easily accomplished from the steam drum. However, some rows of tubes are not accessible from the steam drum and must be cleaned from the water drum or header. The lower ends of ALL tubes must be cleaned from the water drum or header. You will also find tubes that are bent in such a way that brushes cannot be forced around the bend without breaking the tube cleaner. These tubes must be cleaned from both ends.

Tube cleaners must be kept in good operating condition. The rotor and blades of the air motor should be kept clean and well lubricated. The hose connections should be kept tight and free from leaks. The ships or flexible shafts should be inspected frequently and renewed if they show signs of wear or damage. If the brushes become too worn to work efficiently, the body of the brush should be retained and a new set of brush refills inserted. When replacing parts on tube cleaners, use only the tools provided for this purpose and be careful not to exert unnecessary pressure. Store tube cleaners in a clean, dry container. Wrap the turbine rotor and casing in a slightly oily rag to prevent rusting.

After all tubes, drums, and headers have been cleaned, and after all tools and equipment have been removed from the watersides, blow through the tubes with air; then wash out the drums, tubes, and headers with fresh water. Be particularly careful to remove all accumulations of dirt from handhole seats. Then examine the seats for scars, pits, or other defects that might cause leakage. All bottom blow, header blow, and test cock valves should be inspected and repaired, in accordance with manufacturer's instructions during each waterside cleaning period.

After the washing has been completed, thoroughly dry out the boiler watersides. Inspect the watersides to determine the condition of the metal and to see if the cleaning was satisfactory. Also, inspect the boiler to be sure that all parts are tight. Be sure that all openings between drums and gage glasses, blow valves, and safety valves are clean and free of foreign matter. These openings are sometimes overlooked.

CHEMICAL CLEANING

In most cases, mechanical cleaning is the preferred method for cleaning watersides. Chemical (acid) cleaning requires special authorization since it involves the use of elaborate and costly equipment and rather extensive safety precautions. However, you may have occasion to use the chemical method, so a limited discussion on it is given here.

Inhibited acid cleaning is used extensively to remove mill scale from the watersides of new or recently serviced boilers. Acid cleaning of boilers has the following important advantages when compared with mechanical cleaning:

1. Less outage time is required.
2. There is less dismantling of the unit.
3. Lower cost and labor requirements.
4. Acid reaches areas inaccessible to mechanical cleaners to do a more thorough job.
5. Because the cleaning is more complete, it is possible to examine the unit thoroughly for defects such as cracks and corrosion pitting.

Acids for Cleaning Boilers

The following acids are used to clean boilers:

1. Hydrocholoric acid.
2. Phosphoric acid.
3. Sulfamic acid.
4. Citric acid.
5. Sulfuric acid.

The chemical most frequently used for boiler cleaning is HYDROCHLORIC ACID. It has a relatively low cost and satisfactory inhibitors are available. The chemical reactions with the boiler deposits usually result in soluble chlorides.

PHOSPHORIC ACID can remove mill scale from new boilers. With this acid, the boiler can be fired directly without producing noxious or corrosive fumes. Direct firing produces good circulation and distribution of the cleaning solution. Another advantage of phosphoric acid cleaning is that the metal surfaces are resistant to corrosion after cleaning. When cleaned with phosphoric acid, metal surfaces must be protected from surface corrosion during draining and before neutralization.

SULFURIC ACID is available in powder form that must be placed in solution. The powdered acid is easier and safer to handle than liquid acids in carboys. It does not produce noxious fumes as it dissolves and it is less corrosive than hydrochloric acid, especially at higher concentrations and temperatures.

CITRIC ACID and SULFURIC ACID are used for removing boiler waterside deposits. Sulfuric acid is economical and easily inhibited. However, a danger is that the sulfuric acid can form insoluble salts such as calcium sulfate.

Inhibitors

Without inhibitors, acid solutions will attack the boiler metal as readily as they attack the deposits. With the addition of suitable inhibitors, the reaction with the boiler metal is greatly reduced. Inhibitors used include arsenic compounds, barium salts, starch, quinolin, and pyridin. Commercial inhibitors are sold under trade names by various chemical concerns. Other inhibitors are manufactured by companies which also furnish complete acid cleaning service.

Safety Precautions

Observe the following safety precautions when acid cleaning a boiler installation:

1. Before acid cleaning, replace all brass or bronze parts temporarily with steel or steel alloy parts.

2. Provide adequate venting for the safe release of acid vapors.

3. Close all valves connecting the boiler with other piping or equipment.

4. Provide competent chemical supervision for the cleaning process.

5. Do not exceed the specified acid and inhibitor maximum allowable temperature. The inhibiting effect decrease with temperature rise and the probability of acid attack of the boiler metal increases.

6. After completion of acid cleaning, be sure to thoroughly flush out all of the tubes that are horizontal or slightly sloping. Obstructions in these tubes can cause poor circulation, overheating, and failure of tubes when the unit is placed in service.

7. Use goggles, rubber gloves and rubber aprons when handling acids.

8. Slowly pour the acid into water when mixing the solutions. CAUTION: NEVER POUR WATER INTO ACID.

9. Do not chemically clean boilers with riveted joints.

10. During acid cleaning, hydrogen gas may be evolved through the reaction of the acid on the boiler metal. Some of the generated gas becomes part of the atmosphere inside the boiler and the remainder is absorbed by the boiler metal, then liberated gradually. Because hydrogen air mixtures are potentially explosive, care must be taken when opening a unit for inspection after acid cleaning. Until the atmosphere within the boiler pressure parts has been definitely cleared of explosive gases, do not use open flames, flashlights, lighting equipment or anything which might produce a spark near the openings to the

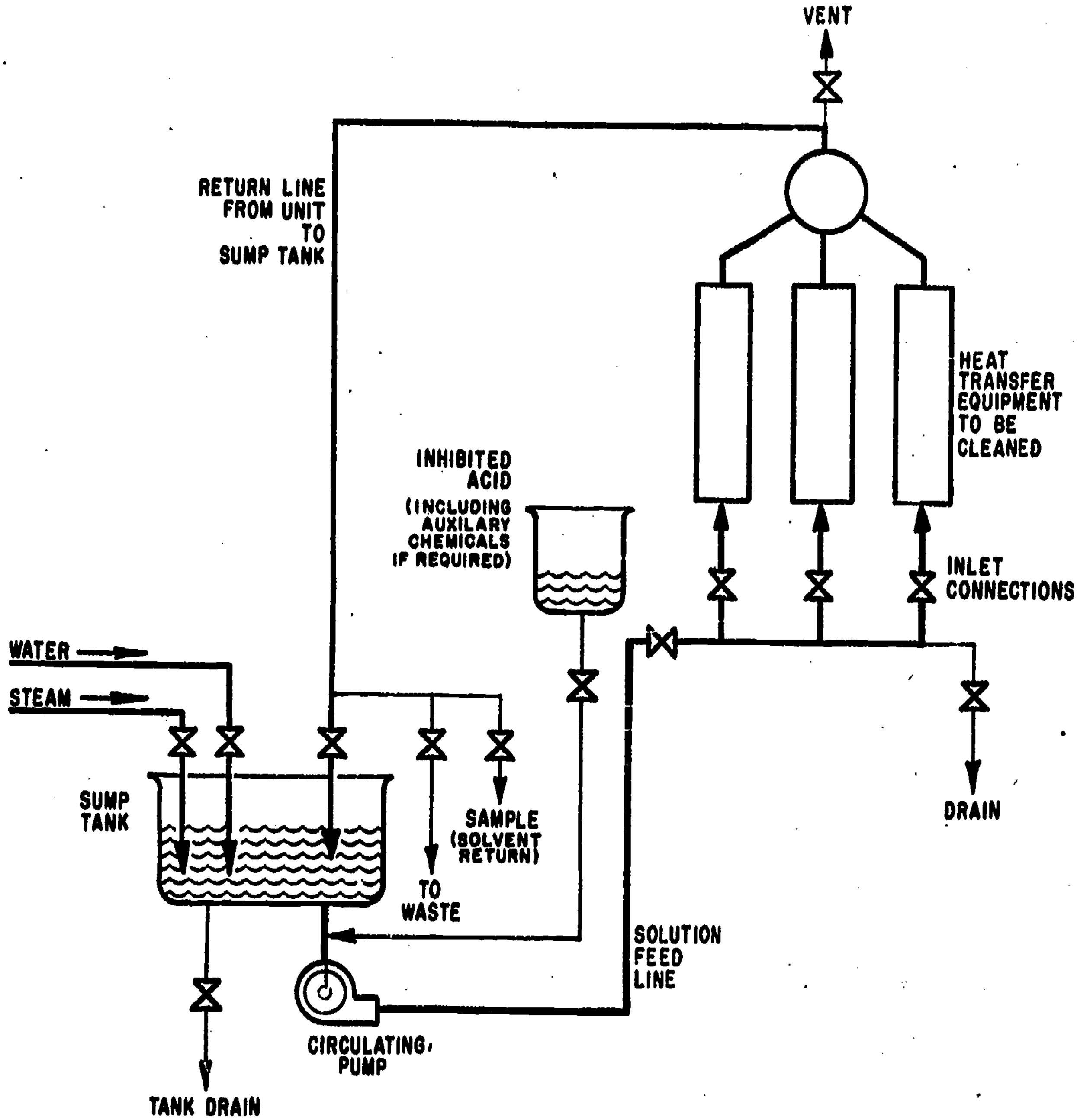

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Figure 16-5.—Acid cleaning by circulation method.

pressure parts and do not enter the boiler. The unit can be cleared of explosive gases by thoroughly flushing the unit with warm water with a positive overflow from the highest vent openings. The water temperature should be as near to 212° F as possible to accelerate the liberation of hydrogen absorbed in the metal. After opening the unit, place air blowers at the open drum manholes to circulate air through the unit. Use a reliable combustible gas indicator to test the boiler atmosphere for explosive mixtures.

Acid Cleaning Procedures

Boiler units can be acid cleaned by either the "circulation" or "fill and soak" method. The circulation method (see fig. 16-5) can be used to clean units with positive liquid flow paths, such as forced circulation boilers. The inhibited acid solution is circulated through the unit at the correct temperature until test analyses of samples from the return line indicate that the acid strength has reached equilibrium and that no further reaction with the deposits is taking place. Because the strength of the acid solution can be determined frequently during the cleaning process, this method can be more accurately controlled and can use lower strength solutions than the fill and soak method.

The fill and soak method (see fig. 16-6) is used for cleaning units with natural circulation. The boiler unit is filled with the inhibited acid solution at the correct temperature and allowed to soak for the estimated necessary time. It is not possible to obtain accurate representative

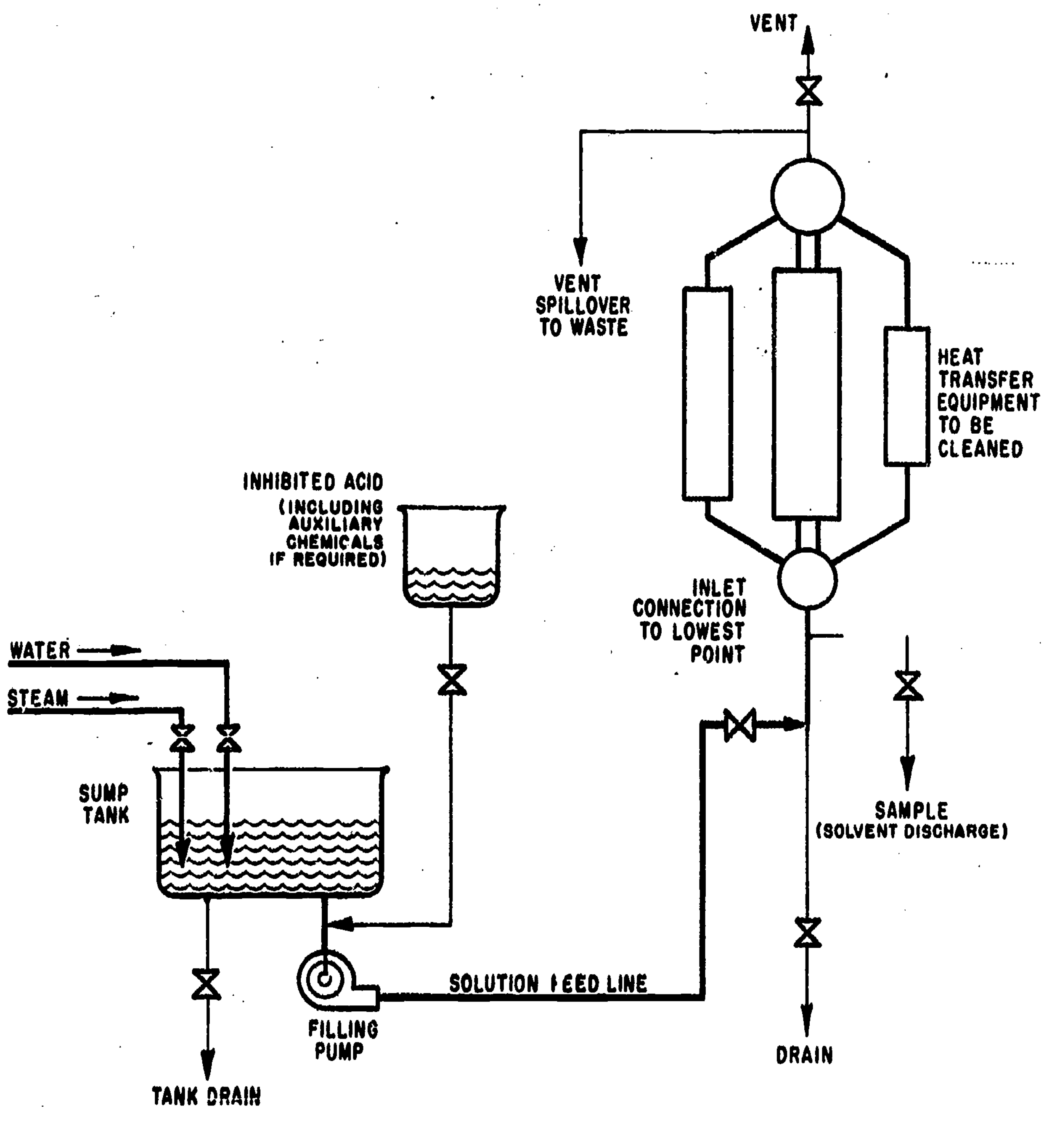

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Figure 16-6. — Acid cleaning by fill and soak method.

samples of the cleaning solution during the soaking period.

Flushing and Neutralizing

1. After acid cleaning, drain and then flush the unit with clean warm water until the flushing water effluent is free of acid and soluble iron salts.

2. Next, a neutralzing solution is circulated through the unit until the effluent shows a definite alkaline reaction. Neutralizing solutions may be of soda ash, trisodium phosphate, sodium tripolyphosphate, or other non-toxic chemicals.

3. After circulation of the neutralizing solution, the water level can be dropped to the normal level and the boiler fired at 50 psig with open vents to permit the escape of liberated gases.

4. Finally, the boiler is again drained and flushed with clean warm water.

BOILING OUT

New boilers, or boilers that have been fouled with grease or scale, should be boiled out with a solution of boiler compound. New boilers must be washed out thoroughly. One method of boiling out is explained below.

Dissolve 5 pounds of caustic soda and 1 1/2 pounds of sodium nitrate, or 10 pounds of trisodium phosphate, for each 1,000 gallons of water the boiler holds at steaming level. Put the mixture into the boiler as a solution. In case of multiple-drum boilers, divide the charge and put equal amounts in each of the lower drums.

Fill the boiler with hot feed water to the level of the bottom of the steam drum. Turn steam into the boiler through the usual boiling-out connections, or bottom blow, and allow the boiler to fill gradually to the top of the gage glass.

Steam pressure in the boiler should be kept between 5 and 10 pounds. The boiling out should continue for 48 hours.

Immediately after boiling out, give a series of bottom blows to remove the bulk of the sludge. The boiler should be cooled, washed out immediately, and given the usual mechanical cleaning.

You may not always use the above method for boiling out. Another method which also gives satisfactory results is described below.

Clean out all loose scale, and any scale adhering to the boiler which can be removed manually. Place about 15 pounds of caustic soda or soda ash and 10 pounds of metaphosphate for each 100 boiler ph in the boiler. Then seal the boiler openings but OPEN ALL VENTS. Fill the boiler approximately three-quarters full with water.

Start the burner and raise the temperature of the water in the boiler to approximately 200°F. Maintain this temperature for 24 to 48 hours. Add make-up water as required during this period to fill the boiler to the base of the safety valve.

Analyze the boiler water during the boil-out period and add enough caustic soda and metaphosphate to maintain the following concentrations:

Causticity as ppm OH 300 to 500
Phosphate as ppm PO_4 100 to 150

Open the boiler at the end of the boil-out period and clean out the sludge and loose scale. Pay particular attention to removing scale and sludge from water legs in firetube boilers. Flush the boiler thoroughly.

If extensive corrosion is exposed when scale is removed, notify your superior so that a boiler inspection may be made.

When the boiler is operated, any residual scale may cause faulty operation. The boiler should be taken out of service at frequent intervals to remove sludges formed from disintegrated scale. As soon as men can work in the boilers, wire-brush the drums and ends of all tubes. Then clean the interior of all tubes, using the approved style of boiler tube cleaning brushes.

You operate all cleaners in the same way. Start the cleaner rotating and insert it in the tube. Pass it slowly along until it comes out the other end of the tube. Immediately reverse the direction and bring the cleaner back through the tube and withdraw it. DON'T STOP the cleaner at any point in the tube as it may cut through the tube. Also be careful not to extend the cleaner too far out at the end of the tube.

After cleaning all the tubes, follow up by blowing them out thoroughly with a strong air jet. Then inspect to see if replacement of any of the tubes is necessary.

REPAIRING BOILER REFRACTORIES

Furnaces are built with high-grade, fire-resistant materials that can and do take a lot of punishment. Sooner or later, however, repairs become necessary. Furnace walls or floor may need repairing. You may get the job and here is a suggested procedure.

First mix the mortar, using a Navy-recommended fire clay or fire cement, and fresh water. Don't add anything else. Make the mortar rather thin and without lumps.

Inspect the bricks for flaws and evenness. Choose the best edge for the furnace side. Dip the brick in fresh water and allow the excess water to drip off.

Then dip one end and side of the brick into mortar, using an edgewise motion to prevent air bubbles from being formed. Lift the brick from the mortar and allow the excess mortar to drip off. Do not place any mortar on the wall or brick with a trowel. The mortar sticking to the brick is all that is used.

If the mortar is too thick you will not obtain thin joints, which are essential to success. The mortar should be a little thinner than the usual wall plaster. You can feel the proper thickness with your hand. Some mortar will stick to your hand as you lift it away from the mortar. Add more clay or water as necessary, and stir the batch at frequent intervals to keep the mortar at the desired consistency.

Place the brick quickly in position in the wall and pound it in place with a wooden mallet until no more mortar can be forced out of the joints. With high-grade brick, joints can be made less than one thirty-second of an inch thick. Joints should never exceed one-sixteenth of an inch.

With a small trowel, fill in any unevenness in the furnace side of the seam and bead over the joints as shown in figure 16-7. Be sure that no edges of the brick are exposed. The wall should be laid up evenly and smoothly. Any excess mortar which protrudes from the joints should be smoothed off with a small trowel so that the corners of the brick are protected.

Allow the wall to dry for about 12 hours, with the burner shutters open to allow circulation of air. This is to permit the escape of

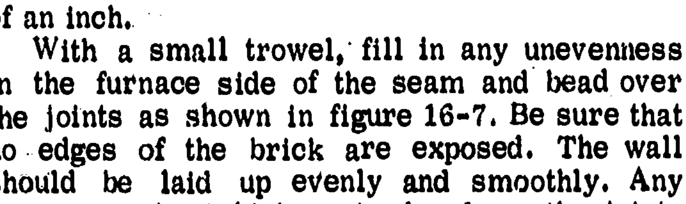

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Figure 16-7. —Cementing brick.

some of the water added to the mortar. As soon thereafter as practicable, light the burner under the boiler and slowly bring the furnace up to operating temperature. This bonds the mortar to the adjacent brickwork.

When inspecting the boiler you may find cracks or holes in the furnace lining. To make necessary repairs, mix some of the fire clay you used for brick mortar into a thin mixture. Use more mortar than you used for the brick mortar mix. Use a trowel to apply this wash.

While standard fire brick generally is used for normal refractory work, plastic fire brick is recommended for emergency patches and for building up furnace openings. Plastic fire brick is unfired fire brick in a stiff plastic condition. It offers a particular advantage in that, because of its plastic nature, it can be pounded into places where otherwise a fire brick of special shape would be required. The fusion point of plastic fire brick is practically equal to that of standard fire brick. Due to the moisture in the plastic material, however, a greater degree of shrinkage will take place. This precludes its general use for side walls. It provides an excellent material, though, for repairing brick work, topping off side and back walls, repairing and constructing the burner openings and, in general, for use in any part of the furnace not exposed to temperature in excess of 3,000° F. It is particularly adapted for use in place of specially formed brick of complicated shapes.

Plastic fire brick material, as received from the factory, ordinarily contains sufficient moisture for working. Care should be taken to avoid the addition of water or any foreign material. In laying up, chunks of plastic just as taken from the can should be rammed tightly into place, preferably in horizontal layers. In general, the more solidly the section of plastic is rammed up the better it will be.

As the next step, the plastic section should be vented with three-sixteenths inch holes. See that the holes extend clear through the plastic and are not more than two inches apart. This allows deeper heat penetration during the baking out process. It also permits ready escape of the steam formed from the moisture in the plastic. DO NOT trowel the surface of a new plastic section. This tends to prevent the escape of steam during baking out.

The plastic section should be held in place with as many anchor bolts as would have been provided had standard fire brick been used instead of plastic.

The plastic section should be air-dried. This will take about 48 to 72 hours, depending upon the atmosphere. As soon as practicable after air drying the furnace should be fired with a small fire, and gradually brought up to operating temperature to complete baking out. Plastic requires a temperature of about 2900° to 3000° F for baking out. If small shrinkage cracks open up during this process, they should be filled with fire clay. In case large cracks occur, they should be filled with plastic.

When used for patches, as in case of brick falling out, the hole should be cleaned out so as to give at least four inches body thickness to the plastic brick. In building up furnace openings the use of a metal form is desirable. However, it is not absolutely necessary if care is exercised to make openings of the proper shape and concentric with the atomizer at every point. If furnace openings as built have a smooth surface, they should be roughened with a stiff wire brush prior to baking out.

REMOVING BOILER TUBES

Boiler tubes are made of a special steel designed to withstand a maximum pressure and temperature. The removal of defective tubes for renewal purposes is an important phase of your job as Utilitiesman.

A recommended procedure for removing boiler tubes from a fire tube boiler consists of three steps:

FIRST: Using a flat chisel, split the ends in two places, about three-fourths of an inch apart, from the end of the tube up to the tube sheet.

SECOND: Split the tube through and beyond the sheet, using a half-round chisel and being careful to avoid scoring the tube sheet.

THRID: Force the 3/4-inch piece up and into the center of the tube, using a blunt-nosed chisel, and exercising care to avoid damage to the tube sheet.

RENEWING BOILER TUBES

All badly warped tubes, tubes in which the belling is likely to give trouble, and tubes that leak after having been expanded must be replaced. Tubes should NEVER be straightened in place, as joints are liable to be strained, causing leaks and possible permanent injury to other parts of the boiler.

After removing the defective tubes — according to the 3-step procedure already described — you are ready to proceed with the replacement. Here's the procedure to follow:

1. Using emery cloth, thoroughly clean the hole in the tube sheet of all rust.
2. Clean the end of the boiler tube to be expanded in the tube sheet. Polish the outside surface of the tube. For a good polish job, first use a file to remove mill scale, then an emery cloth to remove file marks. If done right, the tube end should have a bright polish.
3. Insert the tube in the tube sheet. All tubes should extend through the tube sheet not less than twice the wall thickness.
4. Clean the tube expander of all grit and put a few drops of oil on the rollers.

   NOTE: There are various types of expanders, consisting essentially of three rollers, a body, and a mandrel. The thickness of the tube sheet should be considered in selecting an expander for a particular job. The rollers of the expander should be at least three-eighths of an inch longer than the thickness of the tube sheet if complete expansion of the tube is to be obtained.
5. Put the expander inside the tube end to be expanded, and expand the tube until it is tightly in place. A point to remember is that steel tubes should be expanded just enough to secure tightness, so that ample life may be left in the metal for future expanding should it be found necessary. The expanding should continue only until the rollers appear to operate evenly all around with sufficient pressure on the tool. The judgment of the operator must govern this point as no fixed amount of expanding can be specified in the case of repair work where tube holes vary slightly in size.
6. As a safeguard against pulling out, all tube ends of water-tube boilers are expanded and belled. The ends of fire-tube boilers are expanded, belled, and beaded. The belling of tubes should be at least 1/8 of an inch increase over the outside diameter of the tube being installed.

In an emergency, when spare parts are not available or when the boiler cannot be spared from service long enough to effect tube replacement, a frequently used expedient is to plug the ends of a leaky tube, rendering it inoperative. This measure will, of course, result in the steam generating capacity of the boiler being slightly reduced. For this reason, plugged tubes must be replaced as soon as possible.

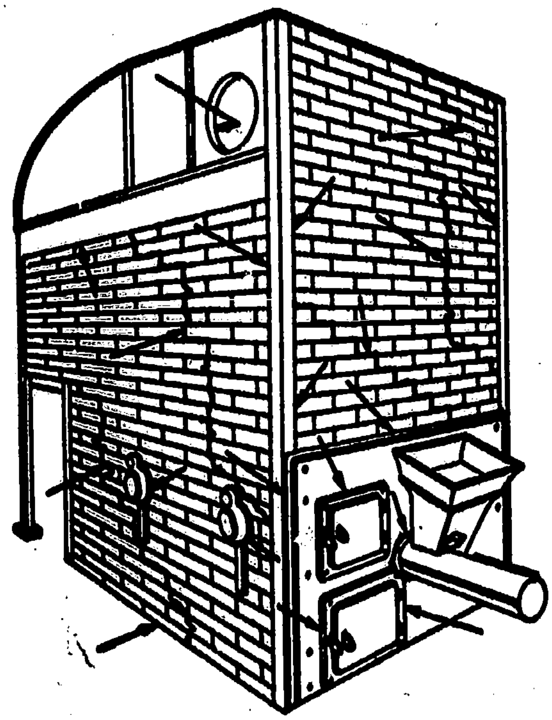

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Figure 16-8.—Places on boiler to be checked for leaks.

MAINTENANCE OF BOILER SETTINGS

The boiler is an expensive item. Besides keeping it clean you will have to stop air leaks, if the boiler is to have a normal useful life.

Immediate action is necessary when a leak appears. Leaks in boilers become larger if allowed to persist.

Cracks and leaks usually start around drums or other places where there is a strain on the setting (fig. 16-8). These cracks should be sealed immediately with a filler material. Use only a Navy-approved joint sealing compound.

You may also find leaks around the anchor bolts used to support the furnace brickwork. These leaks may be reduced, if not stopped entirely, by making a small wick of the sealing compound and wrapping it around the anchor bolt shank between the furnace casing and the washer. Air leaks cause temperature changes that can damage boiler metal and reduce combustion efficiency.

MAINTENANCE REQUIREMENTS FOR CONTROL OF WATER LEVEL

The boiler needs one pound of water to replace each pound of steam discharged from the boiler. Bear in mind that boiling water will have steam bubbles; hence, the water level may not be a true indication of the amount of water in the boiler. The rise and fall of the water level due to this bubbling is known as SWELL.

The need for proper control of water level cannot be overemphasized. If the water level is too low, the boiler may be damaged by overheating, or it may explode. If the water level is too high, priming will occur, where some water is carried out with the steam, causing deposits to form in pipelines, valves, and other equipment. The low-water alarms and various water-indicating and recording gages assist the operator in maintaining proper water level in the boiler. Since the gage glass and try cocks are the most reliable means of determining true water level, they should be used as a final check.

REPLACEMENT OF GAGE GLASSES

Gage glasses have valves at both top and bottom. Hand-operated valves are usually supplied with chains so that if the glass breaks the operator can close valves and avoid danger of burns from escaping steam and hot water. Some gage-glass valves are automatically closed by the rush of steam and water if the glass breaks. Determine the type of valves employed on all gage glasses and decide what to do when a gage glass breaks.

Because of the effect of the gage glass on safe operation, a special effort should be made to prevent defects which would cause a false water-level indication. A broken water gage should be replaced promptly. You may get the job. The following procedure may be useful as a guide in replacing the gage glass.

Start by closing the upper and lower valves securely. Remove the packing nuts, packing, and pieces of broken glass. Then insert the new glass and packing, and tighten the packing nuts. Now turn on the upper steam valve and heat the new glass uniformly. As a safety precaution always wear goggles, and use a wire mesh or canvas screen when putting pressure on the gage glass.

MAINTENANCE OF FEEDWATER REGULATORS

Proper control of water level requires, also, that the feed-water regulator be maintained in top operating condition. Here are a few pointers applicable to the regulators.

In case of a considerable change in the water level from its normal position, make sure you adjust the bypass to manual operation and check promptly for the source of failure. If leaks develop around packed stems, you will want to see that they are stopped immediately. Of course, if the boiler is off the line, it is important that you close the hand valve in the feed line. Bear in mind that the regulator is not designed for use as a stop valve. About once every 3 months you will probably be called on to assist in blowing down the steam and water connections separately.

CARE OF VALVES

Valves deserve special care and attention if they are to serve their intended purpose. In this section we will outline some of the general instructions concerning several different types of valves. First, we should remind you that allowance must be made for variations among activities in the type and frequency of valve inspections, as well as servicing requirements. Therefore, instructions issued by your particular activity should be followed when they differ from those outlined here.

Types of valves which you may be responsible for helping service and maintain, at regular intervals, include (1) stop valves of the globe or gate type; and (2) stop-and-check valves, which combine in one unit an angle or stop valve of the globe type and a check valve. At least once every three months, any of these valves which have not been operated for some time should be operated in order to prevent sticking. Make sure that you also check for leaks, bent stems, missing or broken handle and lubricate the exposed threads and gearing of the valve stem.

You will need to loosen and lift the packing follower about once every three months—or more often. Lubricate the packing with graphite-bearing oil or graphite-bearing grease. Replace the packing followers and tighten sufficiently to ensure against leaks.

Now let us consider briefly the kind of care required for BLOWOFF VALVES. These valves should be opened at least once a day. The amount and frequency of blowing down will depend on a chemical analysis of the water in the boiler concerned.

On a quarterly basis, inspect the blowoff valves at the time the boiler is washed out and when an internal inspection is made. Check the valves for leaks, and inspect the pipe and fittings between the blowoff valves and the boilers. If repairs are needed, see that they are made promptly.

In making a quarterly check on the blowoff valves, do not overlook the insulation, bearing in mind that it should be kept dry. Another item to include is the discharge piping leaking from the valves. Make sure the discharge piping is not mounted so rigidly that proper expansion and contraction will be affected.

Too strong emphasis cannot be placed on the need for keeping SAFETY VALVES in top working order. At regular intervals, depending upon operating conditions, the safety valves must be lifted manually. At least once each year the valves should be tested by raising steam pressure to popping pressure of the respective valve. If safety valves function improperly, report the matter to your immediate supervisor. For detailed information on the maintenance of safety valves refer to the manufacturer's manual.

TESTING AND CALIBRATING PRESSURE GAGES

Gages are delicate instruments, and require care and attention. They are most important to the safe operation of any boiler; they tell you what you need to know about water, heat, and pressure conditions, and eliminate guesswork.

Proper care of gages should include the following:

1. Keeping the dials and face clean.
2. Having the gages well lighted, to facilitate taking the correct reading.
3. Keeping covers tight, and replacing broken glass promptly.
4. Protecting the gages as far as possible from vibration, excessive temperatures, corrosive liquids, and rapid fluctuations in pressure.

PRESSURE GAGE TESTING

Whenever you have reason to believe that a gage is not accurate, you should test it with a dead-weight tester. Figure 16-9 illustrates such a tester. In this type of testing device, the gage under test is subjected to pressure by applying weights to a plunger. The plunger is accurately fitted into a vertical cylinder that contains a water-base hydraulic fluid. (Mineral oil or other petroleum products must NEVER be used in the dead-weight pressure gage tester.) Weights are

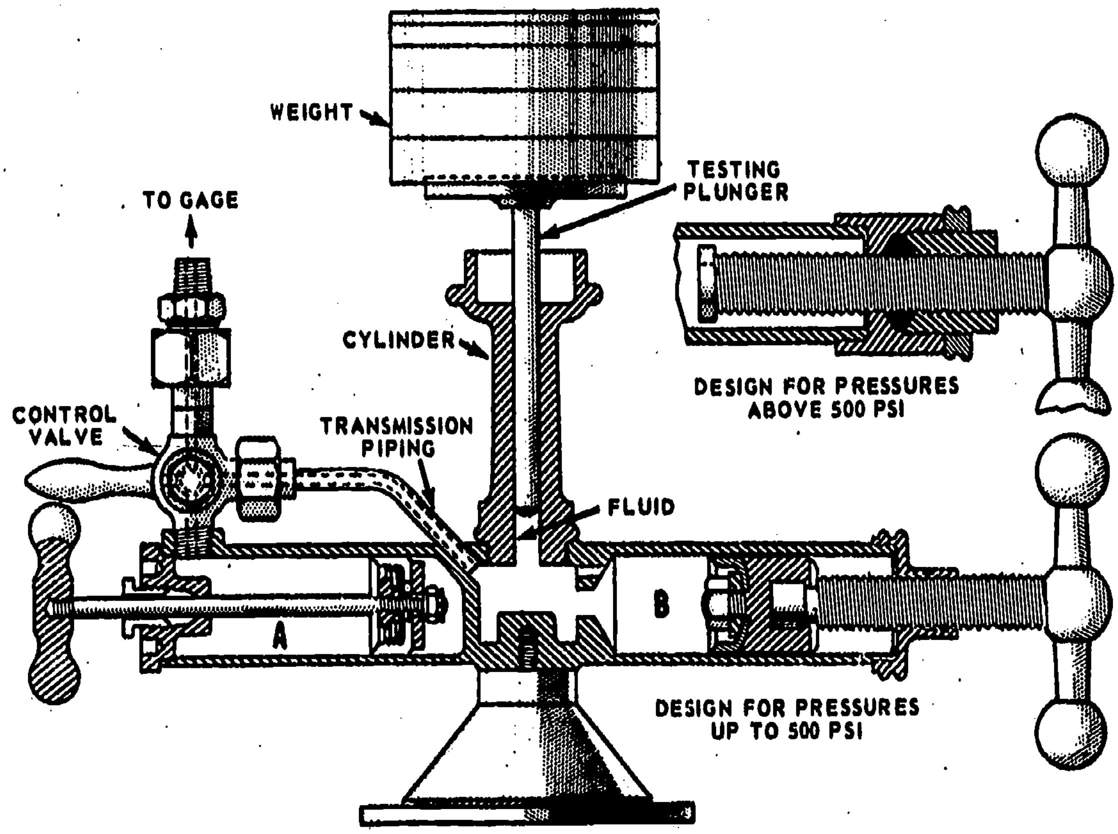

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Figure 16-9.—Dead-weight pressure gage testing apparatus.

applied to the plunger, and the pressure is transmitted to the fluid and then to the gage by way of transmission piping and a control valve. The plunger itself exerts a known pressure (usually 5 psi). Additional weights are provided in sizes that exert pressures equal to 5, 10, and 20 psi.

In figure 16-9, notice that there are two horizontal cylinders in addition to the main vertical cylinder. Cylinder A and its plunger are used to pump the hydraulic fluid into the instrument when it is first filled. The plunger in cylinder B is used to exert a sufficient force on the fluid so that the testing plunger maintains the weight platform in position about 2 inches above the top of the vertical cylinder. At the beginning of the test, the plunger in cylinder B should be screwed out as far as it will go so that cylinder B (as well as the main cylinder) will be filled with fluid. If the weighted test plunger is pushed too far down at any time during the test, the plunger in cylinder B should be screwed in as far as necessary to force the test plunger up so that it will have freedom of movement.

To test a pressure gage in the dead-weight tester, connect the gage to the apparatus and fill the tester with the proper water-base hydraulic fluid, if necessary. (Some testers of this type are designed to be kept full of fluid at all times, but others require filling before each use.) Then level the tester. Apply weights to the testing plunger, as required, and check the pressure gage readings for accuracy. The plunger should be gently rotated as each weight is added, to ensure its freedom of movement. If the gage reading increases by the proper amount as each weight is added, and if the gage reading is equal to the pressure represented by the total weight added, the gage is in adjustment. If the gage is not in correct adjustment, it must be adjusted to read correctly.

PRESSURE GAGE ADJUSTMENT

If a Bourdon-tube pressure gage is found to be inaccurate, the following adjustments may be made:

1. If the pointer travels too far or not far enough, as each weight is applied, the fault

should be corrected by changing the ratio of movement between the Bourdon tube and the pointer. The movement of the sector gear, which meshes with a pinion on the pointer spindle. Lengthening the distance between the pointer spindle and the link connection to the sector gear will reduce the amount of travel to the pointer. Shortening this distance will increase the amount of travel. The relationship between various parts of a Bourdon-tube pressure gage is illustrated in figure 15-16.

2. If the amount of travel is correct as each weight is added, but if the total reading is wrong, the pointer must be reset. Gages of recent design have a countersunk split-head screw in the dial for setting the pointer. On some oiler types of gages, the pointer must be pulled and reset. Pointer pullers are supplied with the gage testing apparatus.

3. If the gage cannot be made to read correctly over the entire scale, it should be adjusted so that the reading is correct at the working pressure. A table or curve should then be made which will show the corrections required for other readings.

From time to time you may be required to adjust diaphragm-type air pressure gages. The zero adjustment on these gages should be checked frequently. Each gage of this type has a 3-way cock that can be turned to shut off the gage without disconnecting the gage piping. When the handle of the 3-way cock is at right angles to the valve body, the gage unit is open to the outside air pressure and the reading on the scale should be zero. When the handle of the cock is parallel to the valve body, the gage is open to the pressure in the line.

A zero adjusting screw is provided either below the gage or on one side of the gage. Turn this screw in or out, as required to bring the pointer to zero, while the handle of the 3-way cock is at right angles to the valve body. After making this zero adjustment, restore the gage to service by turning the cock handle so that it is again parallel with the valve body.

MINOR REPAIR OF PRESSURE GAGES

If you are required to replace any part of a pressure gage, handle the mechanism carefully so that none of the elements will be bent or distorted.

You may occasionally be required to replace the diaphragm in a diaphragm-type air pressure gage (fig. 16-10). To do this, first disconnect the pressure line below the unit. Remove the outside zero adjustment screw and the 3-way cock (with its coupling) and remove the unit from its case.

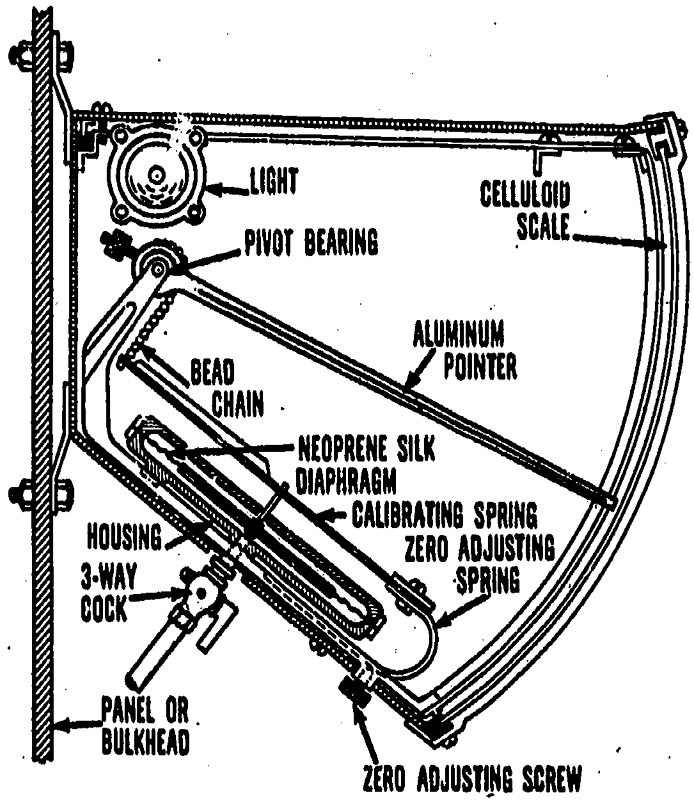

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Figure 16-10.—Diaphragm-type air pressure gage.

Disassemble the unit by compressing the small spring on top of the calibrating spring. This will loosen the retaining pin. Remove the stem that holds the calibrating spring, and remove the screws (usually 10) around the edge of the diaphragm housing. The oil diaphragm can then be lifted out.

Clean both surfaces of the housing. Apply a small amount of gasket cement to the edge of the lower housing, and immediately place the new diaphragm-gasket assembly over the edge of the lower housing. Replace the top housing. Tighten the screws, being careful to draw them up uniformly. Replace the calibrating spring stem, compress the spring, and insert the retaining pin in the stem. Then replace the unit in the case, and the gage is ready for service.

STEAM INJECTOR MAINTENANCE

With injectors, very little is required in the way of maintenance. At times, however, it will be necessary to reseat the overflow and ring valve. Lime deposits also can reduce the operation by closing down the size of the combining and delivery tubes. A good way to remove lime deposits is to place the injector in a tube of muriatic acid for several hours.

To clean the injector, remove the bottom plug. (If you are not familiar with the location of the bottom plug, refer back to figure 15-20.) The delivery tube and ring valve will drop out. Examine and clean all passages and holes. After cleaning, replace the delivery tube and the ring valve by setting them in the plug (which acts as a guide) and screw tightly in place.

MAINTENANCE OF STEAM TRAPS

Once each month, see that steam traps are tested for correct operation. Methods used in testing steam traps (such as the test valve method, the glove test method, etc.) are discussed in chapter 15 of this training manual.

Once a year, or more often if required, dismantle and clean all traps. Inspect for the following:

1. Accumulation of foreign matter.
2. Plugging of orifices, valves, and vents.
3. Cracked, corroded, broken, loose, worn, or defective parts.
4. Excessive wear, grooving, and wire drawing of valves and seats.
5. Defective bellows, buckets, or floats.
6. Leaky vessels and pipes.
7. Defective bypass valves.

Repair or replace defective parts as required following yearly inspection. Replace or repair all defective gaskets, bellows, valves, valve seats, floats, buckets, linkages, and orifices. Use only matched sets of replacement valves and seats. Make certain all replacement parts are of the correct size. Do not change the weight of floats or buckets when repairing traps, or operation may be affected. Often, it is more economical to purchase and install new parts than to recondition defective elements. Repair or replace leaking bypass valves. Repack valve stems.

CARE OF FANS

The forced-draft fan should be checked daily to prevent accumulation of dust in or around the fan. Keep the fan clean! Also, check daily on the sound of the fan; if it is not normal, report the matter promptly to your supervisor.

A daily check should also be made to ensure adequate lubrication of the fan. The temperature is another item which should not be overlooked. This you can test by feel. In case of excessive temperature, notify your supervisor immediately.

Because induced-draft fans are exposed to hot dirty gases, they must be observed closely to prevent operating difficulty. Taking proper care of the fan requires that attention be given DAILY to ensure that the following conditions are properly met:

(1) Bearings are kept cool and well lubricated.
(2) Fan is kept clean. Also, see that any change from the normal in sound is reported promptly to your supervisor.

MAINTENANCE OF FUEL OIL SYSTEMS

Among the major duties of the UT 3 or 2 are those involving troubleshooting and servicing of oil burners. To keep the burner in good operating condition you must be able to recognize the symptoms of various types of trouble and must know how to make various service and maintenance adjustments to the burner.

Before getting into this discussion on troubleshooting and servicing of oil burners, let us point out that the type of burner with which we are primarily concerned is a SMALL, DOMESTIC-TYPE, AUTOMATICALLY OPERATED OIL BURNER FOR LIGHT FUELS. Bear in mind, also, that some variation can be expected in the operation and maintenance of different makes and models of oil burner. It is important, therefore, that you familiarize yourself with the procedures set forth in the manufacturer's instruction manual furnished with the unit you are using. Keep the manual handy as a ready reference, and use it as a guide in locating the source of trouble and for making operating and service adjustments necessary to correct defects in the burner.

In operating a boiler, it will pay you to be constantly on the watch for signs of trouble. If you notice the furnace PULSATING ON STARTING, STOPPING, OR DURING OPERATION, you will want to check all the nozzle-electrode assembly adjustments and blast tubes in relation to each other. Make sure the draft is proper and that there is no down-draft. If the draft is not strong enough, correct by changing the setting on the draft regulator. If necessary, check the chimney for leaks causing poor draft.

If the pulsating is caused by a defective nozzle, the remedy, of course, is to put on a new one. You will want, also, to be sure that air is out of the line between the fuel unit and nozzle. Air trapped here compresses during burner operation and expands when the burner stops. This causes oil to squirt at the nozzle and a bubble to form when the burner shuts down. It is best to delay making final adjustments to a new burner until all air has been purged from the fuel system.

In cleaning the nozzle, remember that it is a delicate device and must be handled with care. It should be cleaned carefully. To cut grease or gum, use kerosene or safety solvent. To blow dirt out of the nozzle, use compressed air. Goggles should be worn to protect the eyes when using compressed air. Never use a metal needle to clean the orifice. Instead, sharpen the end of a match, or use a brush bristle. The socket wrench is the correct tool to use in turning the nozzle. You will want to make sure the nozzle seat is clean. To ensure a tight oil seal, back the bottom off and retighten several times. However, do not get it too tight, or the brass threads may strip and make it difficult to remove.

If the burner has a RAW, STRINGY FLAME, check the air adjustment to make sure it is not open too wide. Too much air makes a poor fire and causes the surplus raw oil to soak into the firebrick. The nozzle is another item to check in locating the source of trouble. If the nozzle is partially plugged, clean or replace it with a new one. A raw, stringy flame is sometimes due to air in the pump. When this seems to be the trouble, open the petcock on the pressure gage to purge the air from the system.

In making a troubleshooting inspection, always check the IGNITION POINTS to make sure there is no accumulation of carbon on them. If you find carbon on the ignition points, first ascertain whether the nozzle is in good condition. If so, move the ignition points up if in spray. In checking the nozzle, make sure it is tight in its holder. If loose, oil is likely to leak out and cause an accumulation of carbon on the electrodes. It is also a good idea to check on the shut-down of the burner to determine whether there is a clean cutoff of oil by the pressure-regulating valve. After the burner is stopped, there should be NO DRIBBLE of oil into the furnace. This condition is to be avoided as it is likely to cause a flareback.

Another common failure to expect in the oil burner is NOISE IN THE OIL PUMP. The noise usually is caused by air in the oil lines. Therefore, first purge the air from the oil lines. To do this, simply loosen the vent plug where the pressure gage is attached. When this does not correct the trouble, a plugged strainer or condensed water in the oil tank are the two most likely suspects. The noise here results from the excessive suction which these conditions exert on the oil line. As a remedy, clean the strainer in the pump and, also, clean the strainer on the fuel line. Also, check for leaks in the suction line. Leaks in overhead piping, above the liquid level in the storage tank, will permit air to enter the oil line.

A point to note is that with some very light oils, an overhead pipeline allows air in the oil to settle out and collect in bubbles. Air can then come through and obstruct pipe action. Two-pipe systems minimize this danger.

If the trouble is FREQUENT RECYCLING, check to make sure the heating element in the room thermostat is screwed in tight. With that done, check for reverse wiring or incorrect splicing, as well as for reversed wiring at the flame-failure device. Then check the thermostat for proper adjustment.

In locating the source of frequent recycling, do not overlook the nozzle. On this score, remember that if the nozzle is too large for the unit, it may cause the heat to build up too rapidly. When the trouble lies in the nozzle, the solution, of course, is to replace it with one of the proper size.

If the stack control throws the burner into safety SHUTDOWN, the reason may be due to low voltage. This calls for a check with a recording voltmeter for at least 24 hours, preferably longer. In addition, check the wiring polarity. This is important because if connections are reversed, or if the hot line is where the ground should be, there is sometimes enough leakage through the control to cause a safety shutdown.

If NO OIL is obtained at the NOZZLE, here is how to go about locating the source of trouble:

- Check the fuel tank to see if you have an adequate supply of fuel.
- Check the nozzle to make sure it is not plugged.
- Inspect the suction line for signs of leaking.
- Test to determine whether the pump shaft turns.
- Look for leaks at the strainer gasket and pump shaft seal.

You may encounter a situation where none of these checks disclose the source of the trouble. In this event, loosen the vent plug in the fuel unit (pump) and run the burner to see if fuel flows as far as the fuel unit. If it does, there is something wrong with the unit.

CARE OF FUEL OIL STRAINERS

Strainers and filters are installed in almost all piping systems to prevent the passage of foreign matter that might cause damage to machinery or equipment.

Strainers are installed in the fuel oil service system to catch particles of foreign matter that might otherwise interfere with atomizer operation. Usually, the strainers are installed between the fuel oil heaters and the burner manifold. After the oil has been heated, it is very fluid and readily gives up any foreign particles contained in it.

Duplex strainers of the basket type are usually used in fuel oil service systems. The strainers are installed in such a way that the oil flows from the center of the basket to the outside, leaving dirt and sediment in the basket. Duplex strainers are installed with a valve arrangement that allows you to remove one basket for cleaning while the other basket remains in service. At least two clean baskets should be kept near the strainer so that baskets can be changed and cleaned when necessary.

A duplex pressure gage, installed by means of a 3-way plug cock arrangement, indicates the pressure on each side of the basket in use. If the pressure is noticeably higher on the inlet side than on the outlet side, the basket probably needs to be cleaned. Even if there is no special indication that the basket in use needs to be cleaned, the baskets should be shifted and cleaned once a day as a matter of routine.

Before removing a basket from a duplex strainer, open the drain at the bottom of the casing and drain off all entrapped oil. Back off on the binding screw or head nuts a few turns; if there is no oil seepage around the cover, it is now safe to remove the cover. Remove the basket after inserting a clean strainer basket, replace the cover and close the drain.

CAUTION: Never start to clean a strainer basket without first shifting to the other basket. Serious fires have occurred when inexperienced personnel have tried to remove a strainer basket while it was still in service. A lot of oil can spray out awfully fast if you open up the wrong side of a fuel oil strainer.

REPLACING HANDHOLE AND MANHOLE GASKETS

At each regular boiler overhaul, all manhole and handhole fittings and the gasket seating surfaces on the drums and headers must be cleaned, inspected, and repaired or renewed if necessary. If the plates are warped, distorted, or otherwise damaged, they must be repaired or renewed.

Whenever manholes and handholes are opened, new gaskets must be fitted. After a gasket has once been compressed, it cannot be reused but must be discarded. Be sure to use the correct size and type of gasket. Never use any makeup compound on the seating surfaces when installing the gaskets. Graphite may be used on the threads of the stud to prevent seizure of the nut.

Before installing a new gasket, thoroughly clean the two gasket seating surfaces (one on the drum or header and one on the plate). Be sure that you remove all corrosion products or other surface deposits and all adhering pieces of the old gasket. It is impossible to obtain a tight joint as long as any foreign matter remains on either seating surface or in the corners of the fitting.

Power-driven wire brushes are best for cleaning the seating surfaces. Scraper-type tools should be used only when wire brushes are not sufficient to clean the surface. Scraper-type tools must be used with great care if they are used at all, since they tend to remove too much metal from the seating surfaces.

If the gasket seating surfaces show extensive signs of pitting, it may be necessary to have these surfaces machined or reground. If the seating surface on a manhole or handhole plate is very badly pitted or damaged, it may be

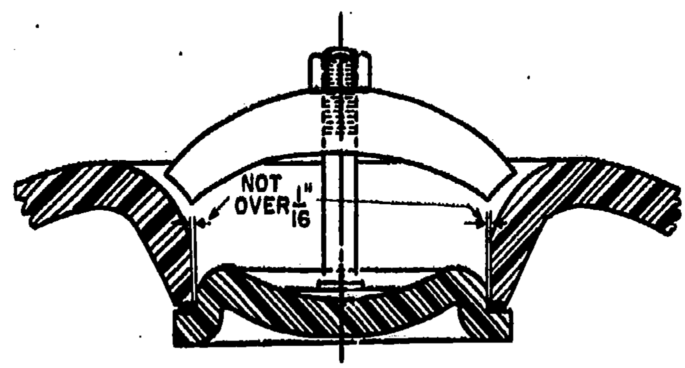

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Figure 16-11.—Manhole plate clearance.

necessary to discard the plate and replace it with a new plate or with one that has previously been machined to blueprint specifications.

The clearance between the shoulder of a manhole plate and the manhole must not exceed 1/16 inch when the plate is centered accurately. Figure 16-11 shows where the clearance is measured. If the clearance is found to be greater than 1/16 inch, the plate should be built up by electric welding at the inner edge of the shoulder. This welding should be done by Steelworkers so that the manhole plate may be stress relieved after it is welded and, so that the welded surface may be remachined.

To ensure proper positioning of a manhole gasket, fit it on the long axis until the inner edge of the gasket fits the shoulder snugly at the ends of the long axis of the manhole plate. The clearance between the gasket and the shoulder should be equalized at the top and bottom of the short axis. Do NOT allow the outer edge of the gasket to protrude at any point beyond the gasket seating surface in the drumhead. If an edge protrudes, the gasket may unravel when it is compressed by the tightening of the manhole cover. Discard any gasket that protrudes beyond the edge of the gasket seating surface.

To install a manhole or handhole plate, first center the fitting in the opening. Make sure that the shoulder does not bind on the edges of the opening. Then slip the yoke on and start the stud nut. Run the nut on the stud until it is handtight, and then give the nut one quarter of a turn with a wrench. Do NOT tighten the nut enough to compress the gasket.

When the boiler is given a hydrostatic test, the pressure of the water usually forces the manhole and handhole gaskets into place and thus ensures proper seating. The plates are first set up lightly. When the boiler is ready for testing, the pressure should be pumped up to within 50 psi of the hydrostatic test pressure, regardless of any leakage from the manhole or handhole plates. Leakage is likely to be general at first, but it will decrease as the pressure is increased. When the pressure is within 50 psi of the test pressure, most of the leakage will stop, although the nuts will still be loose.

If some plates are leaking very badly, the trouble is probably caused by improper seating of the gaskets. As a rule, you will find that the gasket is caught on the outer edge, between the edge of the plate and the edge of the counterbore for the seat. A light blow with a hand hammer on the outside of the plate will usually relieve the tension on the gasket and allow it to seat properly.

After leaky gaskets have been adjusted, and while full test pressure is on the boiler, tighten up all plates firmly. Use only the wrenches specified for this purpose.

Some economizer headers and a few superheater headers are fitted with handhole plugs instead of handhole plates. Also, some economizers have bayonet-type cleanout plugs on the front ends of the tube loops to allow access to the tubes at the return-bend end. Detailed instructions for installing and removing the plug-type manhole fittings and the return-bend cleanout fittings are given in appropriate manufacturer's technical manuals.

HYDROSTATIC TESTS

The boiler should be given a hydrostatic test annually, or whenever the operator is in doubt of the boiler's strength. The purpose of a hydrostatic test is to prove either the TIGHTNESS of all parts of the boiler or the STRENGTH of the boiler and its parts.

In preparing the boiler for a test, rinse it out with fresh water. Then check carefully to see that there is no loose scale or tools left in any part of the boiler.

The procedures for making boiler hydrostatic tests are as follows:

Close all openings and gag (clamp down) all safety valves. Close all connections on the boiler except the air cocks and pressure gage, and the valves of the line through which pressure is to be applied. Reduce water level in the boiler by opening an air cock and blowdown the boiler until the water level is below the feed-water inlet connection. Check the blowdown pit in order to prevent injury to any personnel that may be working in the area.

Connect a hydrostatic pump between the boiler and the building water service connection. Remove the plug from the feed-water inlet cross by turning in a counter-clockwise direction. Use a wrench of the proper size. DON'T use a wrench that would destroy plug shoulders. Install the pipe and fittings between the pump and the boiler. Next, install a hose to the water service. A base main or a feed pump may be used if it develops the required pressure. Remember that the pipes and fittings must be able to withstand pressures.

Open the boiler casing access doors or plates so that tube ends can be inspected during the test. All safety valves should be gagged only handtight to ensure they do not lift by hydrostatic pressure. Be sure that the gag is on straight, otherwise it will slip. DON'T use a wrench; it will bend the valve stem and also might damage the seat. An ordinary gear puller may be used as a gag. Remember that valves are easily damaged if lifted by water pressure.

Install a wedge between the control switch and the pressure actuating platform. Also install a stop valve before the control switch. This will protect the control so that hydrostatic pressure will not actuate or damage the control. The range of the pressure control is usually less than the hydrostatic pressure being applied. DON'T bend or damage the actuating parts.

Fill the boiler with water until water discharges out of the air cock. Close the air cock. Turn on the building water service valve. The water temperature should be equal to the surrounding atmosphere. The minimum water temperature must be 70° F. Make sure that all air is expelled from the boiler drum.

Check the boiler steam pressure gage IN LINE COCK to ensure that it is open. Ensure that the butterfly handle is in the line (parallel) with the tubing.

Apply water pressure of 1 1/2 times the maximum allowable working pressure. To avoid rapid shock and strain, this pressure should be brought up in 10 equal increments, inspecting for leaks and deformities at each increase. Inspect tube ends, boiler seams, and pressure fittings and connections. Make corrections and repairs wherever possible. In case of unusual conditions, DISCONTINUE the TEST IMMEDIATELY and NOTIFY YOUR SENIOR PETTY OFFICER. Care must be taken NOT to exceed the test pressure. NEVER apply more than 10 pounds of pressure above maximum working pressure on a low pressure boiler. Consult the ASME code for testing procedures for other than welded steel boilers.

Secure pressurizing connections. Continuously inspect the boiler tubes, seams, fittings and connections. If the boiler and fittings are tight, the pressure should NOT drop more than 1.5 percent in 4 hours. If loss of pressure is over 1.5 percent, find the leaks and make the necessary repairs.

Following all hydrostatic tests, steam pressure is raised to lift the safety valve. This is to test and set the safety valves and to definitely determine the fitness of the boiler for use.

BOILER WATER TREATMENT

All natural waters contain acid materials and scale-forming compounds of calcium and magnesium, which attack ferrous metals. Some waters contain more scale-forming compounds than others, and some waters are more corrosive than others. Subsurface or well waters are generally more scale-forming, while surface waters are usually corrosive. To prevent scale formation on the internal water-contacted surfaces of a boiler and to prevent destruction of the boiler metal by corrosion, feed and boiler water must be chemically treated. This chemical treatment prolongs the useful life of the boiler and results in appreciable savings in fuel, since maximum heat transfer is possible when no scale deposits occur.

SCALE

A crystal clear water, satisfactory for domestic use, may contain enough scale-forming elements to render it harmful and dangerous in boilers. Two such scale-forming elements are precipitates of hardness and silica.

Scale deposited on the metal surfaces of boilers and auxiliary water heat exchange equipment consists largely of precipitates of the HARDNESS ingredients — calcium and magnesium, and their compounds. Calcium sulfate scale is, next to silica, the most adherent and difficult to remove. Calcium and magnesium carbonates are the most common. Their removal requires tedious hand scraping and internal cleaning by power driven wire brushes. If deposits are thick and hard, the more costly and hazardous method of inhibited acid cleaning is employed. Scale deposits are prevented by: removal of calcium and magnesium in feed water to boiler (external treatment); and chemical treatment of boiler water (phosphate, organic extracts, etc.) changing scale forming compounds to form soft nonadherent sludge instead of scale, easily removed from the boiler by boiler blowdown (internal treatment).

SILICA present in boiler feedwater precipitates and forms a hard, glassy coating on the internal surfaces. In the feed water of high-pressure boilers, such as those used in electric generating plants, a certain amount of silica vaporizes under the influence of high pressure and temperature. The vapor is carried over with steam, and silica deposits on intermediate- and low-pressure blading of turbines. In boilers operating in the range of 20 to 125 psig pressure, the silica problem is not so troublesome. If the water is low in hardness, contains phosphate that prevents calcium silicate scale from forming, or has sufficient alkalinity to keep the silica soluble, no great difficulty is encountered. The amount of soluble silica can be limited by continuous or routine boiler blowdown, which prevents buildup of excessive concentrations.

CORROSION

Corrosion is concurrent with the problem of scale control. Boilers, feedwater heaters, and associated piping must be protected against corrosion. Corrosion results from water that is acidic (contains dissolved oxygen and carbon dioxide). Corrosion is prevented by removing these dissolved gases by deaeration of feedwater, neutralizing traces of dissolved gases in effluent of the deaerating heater by use of suitable chemicals, and by neutralizing acidity in water with an alkali.

METHODS OF TREATMENT

The specific method of chemical treatment employed will vary according to the type of boiler and the specific properties of the water from which the boiler feed is derived. In general, however, the chemical treatment of feed and boiler water is divided into two broad types or methods: external treatment and internal treatment of makeup water for alkalinity control and for removal of scale-forming materials and dissolved gases (oxygen and carbon dioxide) before the water enters the boiler. Internal treatment entails the introduction of chemicals directly to the boiler feedwater or the boiler water inside the boiler. Frequently a combination of both external and internal chemical treatment is used.

External treatment, frequently followed by some internal treatment, often can give better boiler water conditions than integral treatment alone. However, external treatment requires the use of considerable equipment, such as chemical tanks, softening tanks, filters, or beds of minerals and involves high installation costs. Such treatment is therefore used only where the make-up water available is so hard or so high in dissolved minerals, or where conditions of operation are such, that internal treatment by itself does not maintain the desired boiler water conditions. The actual dividing line where the hardness and the concentration of dissolved mineral matter in the water are high enough so that external treatment must be used depends upon mechanical consideration relating to a particular plant, such as the type and design of the boilers, the pressure and rating at which the boilers operate, the percentage of make-up water being used, the amount of sludge that can be tolerated in the boiler, and such general considerations as the space available and the adaptability of the operators.

Many methods of INTERNAL TREATMENT are in use. Most of these treatments utilize carefully controlled boiler water alkalinity, an alkaline phosphate, and organic material. One of the organic materials used is tannin. Tannin is a boiler water sludge dispersant. That is, it makes precipitates more fluid and prevents their jelling into masses that are difficult to remove by blowdown. Because of treatment costs and simplicity of chemical concentration control, the alkaline phosphate-tannin method of internal treatment is perhaps the most widely used method. When properly applied and controlled, this treatment prevents formation of scale on internal boiler surfaces and prevents corrosion of the boiler tubes and shell.

BOILER WATER TESTS

As we have just seen, boiler water must be treated with chemicals to prevent the formation of scale on the internal surface of the boiler, and to prevent deterioration of the boiler metal by corrosion. Testing of boiler water is necessary to determine whether the amount of chemical residuals required to maintain clean boiler surfaces is present. As a Utilitiesman you should be able to make various kinds of boiler water tests. (See fig. 16-12.) The procedure for a few types of tests, which you may be called on to make, will be given here; for instance, tests for hardness, phosphate, tannin, caustic alkalinity (with and without tannin), sodium sulfite, and pH. A test kit is provided for each test. The kit for a particular test will contain the equipment and materials required to make the test.

Before proceeding, here is a brief word of caution which applies to each test that will be discussed: IF THE TESTING PROCEDURE OF THE EQUIPMENT AND/OR REAGENT SUPPLIER DIFFERS FROM THAT PRESCRIBED IN THIS TEXT, THE SUPPLIER'S PROCEDURE SHOULD BE USED.

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Figure 16-12.—Testing boiler water is an important part of your job.

Test for Hardness

Boilers operating at pressures of 15 psi and less are normally used for space heating and hot water generation. Practically all the condensate is returned to the plant. Only a small amount of makeup is required, and secondary feedwater treatment usually is sufficient. When appreciable quantities of steam are used in process work and not returned as condensate to the plant, the problem of scaling and corrosion arises, and more complete treatment of feedwater must be considered.

The ideal water for boilers is one that does not form scale or deposits, that does not pit feedwater system and boiler surfaces, and does not generate appreciable CO_2 in steam. However, such a raw makeup water is impossible to obtain in the natural state from wells or surface sources. It is necessary, therefore, to treat it to the extent that treatment can be justified economically in terms of advantage gained.

Feedwater of 20 to 25 ppm hardness as $CaCO_3$ need not be treated externally for reduction of hardness if sufficient alkalinity is present to precipitate the hardness in the boiler as $CaCO_3$, or if hardness reducers such as phosphates are introduced to combine with and precipitate the hardness. Precipitation of this hardness in a low- or medium-pressure boiler generally will not cause wasteful blowdown. When the mixture of condensate and makeup in a medium-pressure steam plant possesses a hardness greater than 20 to 25 ppm as $CaCO_3$, the hardness should be reduced to 0 to 2 ppm as $CaCO_3$.

Feedwater of a hardness in excess of 2 ppm as $CaCO_3$ should be treated to bring it within the range of 0 to 2 ppm as $CaCO_3$. This small remaining hardness can be precipitated in the boiler by secondary treatment and removed by continuous blowoff equipment.

The test for hardness, as presented here, employs the Colorimetric Titration Method. This test is based on the determination of the total calcium and magnesium content of a sample by titration with a sequestering agent in the presence of an organic dye sensitive to calcium and magnesium ions. The end point is a color change from red to blue. It occurs when all the calcium and magnesium ions are separated.

The following equipment is used in making this test:

One 25-ml burette, automatic, complete
One 210-ml casserole, porcelain
One 50-ml cylinder, graduated
One stirring rod, glass.

The reagents are:

Hardness indicator
Hardness buffer
Hardness titrating solution.

To make the test, start by measuring 50 ml of the sample in the graduated cylinder and transfer it to the casserole. With the calibrated dropper, now add 0.5 ml of the hardness buffer reagent to the sample, and stir. Then add 4 to 6 drops of hardness indicator. If hardness is present, the sample will turn red. Add the hardness titrating solution slowly from the burette, with continued stirring. When approaching the end point, the sample begins to show some blue coloration, but a definite reddish tinge can still be seen. The end point is the final discharge of the reddish tinge. More hardness titrate solution does not produce further color change.

In using this procedure, the hardness titrating solution must be added slowly because the end point is sharp and rapid. For routine hardness determination it is suggested that 50 ml of the sample be measured, but only approximately 40 to 45 ml be added to the casserole at the start of the test. The hardness buffer reagent and the hardness indicator should then be added as directed, and the mixture titrated rapidly to the end point. The remaining portion of the sample should then be added. The hardness present in the remainder of the sample turns the contents of the casserole red again. Titrating is continued slowly until the final end point is reached. A record should be kept of the total milliliters of hardness titrating solution used.

To calculate the results, in ppm hardness, use the following equation:

$$\text{ppm hardness as } CaCO_3 = \frac{\text{ml titrating solution} \times 1000}{\text{ml sample}}$$

Using a 50-ml sample, the hardness in ppm as $CaCO_3$ is equal to the ml of titrating solution employed, multiplied by 20.

Test for Phosphate

This is a colorimetric test for phosphate, employing a decolorizing carbon for removal of tannin. Carbon absorbs the tannin, and the carbon and tannin are then filtered out. When tannin is not present, carbon improves the test for residual phosphate by making the tricalcium phosphate sludge more filterable.

The equipment required for the phosphate test includes:

- One phosphate color comparator block of two-standards — 30 ppm and 60 ppm of phosphate as PO_4. (The Taylor high-phosphate slide comparator may be used instead.)
- Four combination comparator mixing tubes, each marked 5, 15, and 17.5 ml, with stoppers
- One filter funnel, 65-mm diameter
- One package filter paper, 11-cm diameter
- One 20-ml bottle
- One 1/2-ml dropper
- One 1/4-teaspoon measuring spoon
- Two plain test tubes, 22 mm x 175 mm (about 50 ml)
- Two rubber stoppers, No. 3 flask
- One 250-ml glass-stoppered bottle, labeled Comparator Molybdate Reagent.

The reagents you will need are:

- One 32-oz comparator molybdate
- One 2-oz concentrated stannous chloride
- One 32-oz standard phosphate test solution (45 ppm of phosphate, PO_4)
- One lb decolorizing carbon. (This is a special grade of decolorizing carbon that has been tested to make sure it does not affect the phosphate concentration in the sample.)

For test purposes, the stannous chloride is supplied in concentrated form. The reagent must be diluted and should be prepared from the concentrated stannous chloride on the day it is to be used, because the diluted solution deteriorates too rapidly for supply by a central laboratory. If not fresh, dilute stannous chloride gives low test results. Concentrated stannous chloride also deteriorates in time and should not be used if more than two months old. Dilute stannous chloride is made by the following method:

1. Fill the 1/2-ml dropper up to the mark with the concentrated stannous chloride.
2. Transfer it to a clean 20-ml bottle.
3. Add distilled water up to the shoulder of the bottle, then stopper and mix by shaking.

Any dilute stannous chloride not used the day it is made should be discarded.

To make the test for phosphate, here is the procedure to follow:

1. Without disturbing any settled sludge, transfer sufficient of the sample to the test tube to fill it about half full.

2. Add 1/4 teaspoonful of decolorizing carbon. Stopper the tube and shake vigorously for about 1 minute. The carbon absorbs the tannin so that it can be filtered out.

3. Fold a filter paper and place it in the filter funnel. Do not wet down the filter paper with water. Filter the shaken sample, using a combination mixing tube as a receiver. The carbon absorbs tannin, and the tannin and sludge present are filtered out more readily. Avoid jiggling the funnel, as unfiltered boiler water may overflow the edge of the filter paper into the tube. It may be necessary to provide a support for the funnel. Filtering is slow because of the action of carbon.

4. After 5 ml of sample has filtered through, as indicated by the level in the tube, discard it. Continue filtering to bring the level in the test tube again up to the 5 ml mark. The sample should come through clear and free, or nearly free, of any color resulting from the tannin. If not nearly free of tannin color, repeat the test

using 1/2 teaspoon of carbon, adding it in two 1/4 teaspoon portions, shaking it for a minute after each addition.

5. Add comparator molybdate reagent to bring the level up to the second mark (15 ml). Stopper and mix by inverting the tube several times.

6. Add fresh dilute stannous chloride up to the third mark (17.5 ml). Stopper and mix by inverting. If phosphate is present, the solution in the mixing tube turns blue.

7. Place the tube in the comparator block. Compare the color of the solution in the tube with the standard colors of the phosphate color block. Colors between the two standard colors may be estimated. Take the reading within 1 minute after adding the stannous chloride, because the color shortly fades.

8. Record the results as LOW, if below 30 ppm; HIGH, if above 60 ppm; or OK, if between 30 and 60 ppm.

Tannin Test

The purpose of the TANNIN TEST is to determine the amount of tannin in the boiling water. Tannin is used to hold sludge in suspension. In treating boiler water with tannin, the dosage can be controlled by the depth of brown formed in the boiler water by the tannin. To estimate the depth of the color, which is necessary in adjusting tannin dosages, a sample of the boiler water is compared with a series of brown color standards of successively increased depths of color. A tannin color comparator, which is used for the comparison, has five glass color standards: No. 1, very light; No. 2, light; No. 3, medium; No. 4, dark; and No. 5, very dark.

The kit for the tannin test contains:

One tannin color comparator
Two square tubes, 13 mm viewing depth
One plain test tube, 22 mm x 175 mm
One filter funnel, 65 mm x 65 mm
One package of filter paper, 11-cm diameter.

In making this test, first fill a plain test tube almost to the top with cool boiler water. Then place a square test tube in the slot of the comparator, and insert the filter funnel in it. Fold a filter paper and place it in the funnel without wetting it down. Filter water from the plain test tube into the square tube until the tube is nearly full.

Remove the square tube from the comparator and hold it up to a good source of natural light. Note the appearance of the filtered boiler water. It should be free of suspended solids and sludge. If it is not, refilter the sample, using the same funnel and filter paper. Repeat, using double filter paper if necessary, until the sample does come through free of suspended solids and sludge.

To complete the test, place the square tube of filtered sample in the middle slot of the comparator. Then compare the color of the sample with the five standards, viewing it against a good source of naural light. The color standard most closely matching the color of the filtered sample gives the tannin concentration of the boiler water. For a number of boiler water conditions, the tannin dosage is usually satisfactory if it maintains a medium (No. 3) tannin color. If the tannin color is too high, blowdown; if too low, add tannin.

Test For Caustic Alkalinity (OH) Without Tannin

The boiler water sample for this test is collected at a temperature of 70° F, or below.

The equipment required is as follows:

Two 8-in. droppers with bulbs
Two 250-ml glass-stoppered bottles, labeled Causticity No. 1 and Causticity No. 2
Four marked test tubes, 22 mm x 185 mm
Three plain test tubes, 22 mm x 175 mm
Three rubber stoppers, No. 2
One 14-in. test-tube brush
One test-tube clamp
Two 9-in. stirring rods
One 1-oz indicator dropping bottle for phenolphthalein
One test tube rack.

The following reagents also are required:

One 24-oz bottle causticity reagent No. 1
One 24-oz bottle causticity reagent No. 2
One 4-oz bottle of phenolphthalein indicator.

Here are the steps to follow in conducting a test for causticity when tannin IS NOT used. But first, as a word of caution: AVOID EXPOSURE OF THE SAMPLE TO THE AIR AS MUCH AS POSSIBLE TO MINIMIZE ABSORPTION OF CO_2.

1. Without disturbing any settled sludge, fill a marked test tube exactly to the first mark

(25 ml) with some of the original boiler water sample.

2. Shake causticity reagent No. 1 (barium chloride solution saturated with phenolphthalein) thoroughly and add enough to the graduated tube to bring the level exactly to the second, or long, mark (30 ml). Stir the solution with the 9-inch stirring rod, which must be kept clean and reserved for the causticity test only. If the mixture remains colorless or does not turn pink, the causticity in the boiler water is zero. In this case the test is finished.

3. If the mixture turns pink, causticity is present. (If the pink color is not very deep, intensify it by adding two drops of phenolphthalein indicator to the mixture in the tube.) Add causticity reagent No. 2 (standard 1/30 normal acid), using the 8-inch dropper, which must be kept clean and reserved for the causticity test only. Causticity reagent No. 2 is sucked from the reagent bottle into the dropper by its rubber bulb and added, drop by drop, to the test tube. After each addition, stir the mixture with a stirring rod. After sufficient reagent has been added, the pink color disappears, the change point usually being very sharp. As soon as the pink color just fades out, stop adding reagent.

4. The amount of causticity reagent No. 2 required to make the pink color disappear indicates the concentration of hydroxide (OH) or causticity in the boiler water. The amount of reagent used is shown by the marks on the test tube above the long mark (30 ml). The distance between any two marks on the test tube equals 5 ml, and readings less than 5 ml can be estimated. For example, if only 3/5 the distance between the long mark and the next mark above was filled, then 3 ml were added. If the distance filled was past one mark plus 3/5 the distance to the next, then 5 + 3 = 8 ml were used. To obtain the actual ppm of hydroxide or causticity shown by the test, multiply the number of ml by 23. This constant number, 23, represents the amount of sodium hydroxide present in the boiler water by volume. Thus, for 8 ml of causticity reagent No. 2, there are 8 x 23 = 184 ppm hydroxide or causticity in the water.

5. Record the results of the test in a boiler log or a chemical log and adjust the range to meet requirements. If causticity is too high, blowdown; if too low, add sodium hydroxide (caustic soda).

Test For Caustic Alkalinity (OH) With Tannin

For this test, it is desirable to start with a warm sample of about 160° F. It may be reheated by placing the sample-collecting container in a stream of hot boiler water drawn through the boiler water cooler connection.

In a test for causticity when tannin is used, make sure you observe the following precaution as carefully as when tannin IS NOT used: AVOID EXPOSURE OF THE SAMPLE TO THE AIR AS MUCH AS POSSIBLE TO MINIMIZE ABSORPTION OF CO_2.

The equipment and reagents required for this test are the same as those listed in the preceding section, where tannin was not used.

The procedure for conducting a test for causticity, when tannin is used, can be broken down into the following steps:

1. Fill two test tubes to the first mark (25 ml) with some of the original boiler water sample, taking care not to disturb the settled sludge in the container. (It is important that as little sludge as possible be transferred from the sample-collecting container to the test tubes.)

2. Shake causticity reagent No. 1 thoroughly and add enough to each of the two marked tubes to bring the levels up to the second, or long, mark (30 ml). Stir both with the stirring rod, which must be kept clean and reserved for the causticity test only. Stopper both tubes and let them stand until any sludge formed has settled to the bottom. The sludge carries down with it much of the tannin or other colored matter in the solution; settling takes a few minutes if the sample is warm. Without disturbing the sludge at the bottom, pour enough solution from the tubes into the third marked tube to fill it to the second, or long, mark. Discard the mixture left in the first two. If the sample in the third is still warm, cool it by letting cold water run on the outside of the tube. It is sometimes possible to intensify the pink color by adding two drops of phenolphthalein from the indicator dropping bottle to the sample in the tube. Stir the solution. If it is not pink, the causticity in the boiler water is zero.

3. In that case, the test is finished. But if the mixture turns pink, proceed in the same manner as directed in steps (3), (4), and (5) when NO TANNIN is used.

Perhaps a brief explanation should be given of an ALTERNATE PROCEDURE which can be followed in making the test for causticity when tannin is used. In this procedure any glass container, such as a large test tube or graduated cylinder, marked for 50 to 60 ml can be used instead of two standard marked test tubes used in steps (1) and (2) above. With the large test tube or graduated cylinder, the warm (160° F) sample is added up to the 50-ml mark and causticity reagent No. 1 up to the 60-ml mark. Stir the mixture and stopper the tube or graduate. After the sludge settles, pour off enough of the solution into one of the standard marked test tubes to fill it to the long mark (30 ml). If the sample is warm, cool it by letting cold water run on the outside of the tube. The pink color may be intensified by adding two drops of phenolphthalein. If the solution is not pink, the causticity in the boiler water is zero. But if it turns pink, proceed in the same manner as (3), (4), and (5) when NO TANNIN is used.

Test For Sodium Sulfite

The sample for this test should be cooled to 70° F, or below, and exposed to the air as little as possible, because oxygen in the air combines with sodium sulfite in the sample and causes low readings. It is desirable, therefore, to collect a separate sample, using the boiler water sample cooler, with the line reaching to the bottom of the sampling bottle. The boiler water should be allowed to run until a few bottlesful overflow to waste.

The equipment necessary to make the sodium sulfite test includes these items:

- Two marked test tubes
- Two plain test tubes
- One stopper for plain test tube
- One stirring rod
- One 8-in. dropper
- One ¼ measuring teaspoon
- One 50-ml beaker
- One 150-ml beaker
- One 30-ml acid dropping bottle, with dropper marked at 1/2 ml for hydrochloric acid 3N
- One 30-ml starch dropping bottle, with dropper marked at 1/2 ml for starch indicator.

The reagents required are as follows:

- One 2-oz bottle of potato, or arrowroot, starch
- One 8-ml vial of thymol
- One 24-oz bottle of hydrochloric acid 3N
- One 1-pt amber bottle of standard potassium iodate-iodide reagent.

The starch indicator for this test must be prepared locally. Here is the procedure to follow for good results.

1. Measure out a level 1/4 teaspoonful of potato or arrowroot starch and transfer it to the 50-ml beaker.
2. Add a few milliliters of distilled water and stir the starch into a thin paste, using the end of the stirring rod.
3. Put 50 ml of distilled water into the 150-ml beaker. (It is convenient in this step to have the 150-ml beaker marked at the point where it holds 50 ml, or one of the marked test tubes can be used by filling it with distilled water to the fourth mark above the long mark.)
4. Bring the water in the 150-ml beaker to a boil by any convenient method.
5. Remove the source of heat and immediately pour the starch paste into the boiling water while stirring the solution.
6. Put a crystal of thymol into the starch solution and stir. After the solution has cooled, pour off any scum on the surface and transfer 30 ml to the indicator dropping bottle.

The starch solution loses its sensitivity as an indicator after a time. Addition of the thymol preserves it for about two weeks. The starch should be dated when prepared.

In making the sodium sulfite test, proceed as follows:

1. Transfer 1 ml of hydrochloric acid 3N to a clean, marked test tube by measuring out 1/2-ml portions with the dropper of the acid dropping bottle.
2. From the starch dropping bottle, transfer 1/2 ml of starch to the marked test tube.
3. Without disturbing any settled sludge in the sample, pour enough sample into the marked test tube to bring the level up to the first mark (25 ml). Stir the mixture in the tube with the plunger end of the stirring rod.
4. To add the standard potassium iodate-iodide reagent to the mixture in the marked test tube, it is convenient to have the marked test tube supported and the stirring rod placed in the tube, so that the reagent can be added with one hand while the mixture is stirred with the

other. Fill the 8-in. dropper with standard potassium iodate-iodide reagent from the stock bottle by sucking it up with the rubber bulb. (The dropper must be kept clean and reserved for this test only.)

5. Add the reagent to the mixture in the marked test tube, one drop at a time, counting the number of drops and stirring after each is added until a permanent blue color, which is not removed by stirring, is obtained. The standard iodate-iodide reagent reacts with sodium sulfite in the mixture, and formation of the permanent blue color from the action of excess reagent with the starch shows that all the sodium sulfite in the mixture has been consumed by the iodate-iodide reagent.

6. Each drop of iodate-iodide reagent used (except the last one) indicates 5 ppm of sodium sulfite in the boiler water sample. To figure the concentration of sodium sulfite in the boiler water, multiply the total number of drops of the standard iodate-iodide reagent used, less one, by 5. For example, if 5 drops were used, subtract 1 from 5 = 4, 5 x 4 = 20 ppm.

7. Record the results of the test as ppm.

Test for pH

The value of pH indicates the degree of acidity or alkalinity of a sample. A pH of 7.0 represents the neutral point, lesser values denote acidity, the greater values alkalinity. The test is made as soon as possible after taking the sample. Avoid exposure to air as much as possible to minimize absorption of CO_2.

Equipment used in making the pH test of boiler water includes:

Two vials indicator paper, hydrions pH 10 to 20
Two vials indicator paper, hydrions C pH 11 to 12
One 50-ml beaker
One 2-oz bottle

In conducting the test for pH of boiler water, remove a strip of pH 10-to-12 indicator paper from the vial and dip it into the sample in the beaker. Keep the paper immersed for 30 seconds, then remove it. If the sample does not change the color of the paper, or colors it yellow or very light orange, the pH of the sample is too low and the test is finished. If the paper turns orange or red, the pH is either satisfactory or too high.

In that case, remove a strip of paper of pH 11-to-12 from the vial and dip it into the sample in the beaker. Keep the paper immersed for 30 seconds, then remove it. If the sample does not change the color of the paper, or colors it a light blue, the pH is satisfactory. If the paper turns deep blue, the pH is higher than necessary. In that case blowdown or reduce dosage of caustic soda (NaOH).

pH of Treated Condensate

In making a test for pH of treated condensate, take the sample from a point in the return piping near which condensation takes place, such as after a trap, or preferably where return-line corrosion is known to occur. The sample must be representative of water flowing in the return lines. Water taken from the return tank, especially of large installations, generally shows a higher pH. A sample should not be taken from a collecting tank if other water, such as make-up, is received in the tank.

The equipment required for this test includes:

One 4-oz brown bottle of condensate pH indicator
One 1-oz indicator bottle, with dropper marked at 0.5 ml
One 100-ml beaker, marked at 50 ml
One 9-in. stirring rod, glass

In making a test for pH of treated condensate, proceed as follows:

- Pour a freshly drawn sample into the testing beaker until it is filled to the 50-ml mark. Cooling of the sample is not necessary.
- Transfer 1/2 ml of indicator solution to the 50-ml testing beaker, using the marked dropper. Stir the solution in the beaker.
- If the color change is light pink, the sample is NEUTRAL, or slightly alkaline. The condensate pH is satisfactory and the test is over. Record in a log that the pH range is between 7 and 7.5.
- If the color change is green, the sample is in the acid range and the boiler water must be treated with Amines. Treat the boiler water with Amines gradually (in small amounts at a time), and retest after each treatment. Note: permission to treat with Amines must be obtained from your supervisor. (Amines are volatile, poisonous, and in the alkaline range. Amines are the only chemical used to treat boiler water that

will vaporize and leave with the steam and thereby protect the return system.)
If the color change is red or purple, the sample is in an excessive alkaline (pH) range. In that case, reduce Amines treatment gradually (in small amounts at a single time), and retest after each treatment. Remember, condensate pH normal acceptable range is between 7 and 7.5.

Test For Total Dissolved Solids

The solu-bridge method is a simple and rapid way to determine TDS content. It is based on the fact that ionizable solids in water make the solution conduct electricity. The higher the concentration of ionizable salts, the greater the conductance of the sample. Pure water, free from ionizable solids, possesses a very low conductance and thus a very high resistance. The solu-bridge instrument measures the total ionic concentration of a water sample, the value of which is then converted to parts per million.

The solu-bridge test equipment and reagent are furnished by the supplier in a kit.

CAUTION: The model of the solu-bridge given below is not suitable for measuring solids in condensed steam samples or an effluent of the demineralizing process. Instead, a low-conductivity meter is necessary because of the extremely low solids content of good condensed steam and demineralized water.

The equipment and reagent are:

One solu-bridge, Model RD-P4 or equivalent, for a 105- to 120-v, 50- to 60-cycle a-c outlet. (The model has a range of 500 to 7,000 micromhos/cm.)

One polystyrene dip cell, Model CEL-S2.
One thermometer, 0° to 200° F.
One 0.1-g dipper for gallic acid.
One cylinder, marked at 50-ml level.
Gallic acid powder, 1 lb.
Calibration test solution, 1 qt.

The test is made as follows:

1. Without shaking, pour 50 ml of the sample into the cylinder. Add 2 dippers of gallic acid powder and mix thoroughly with a stirring rod.

2. Connect the dip-cell leads to the terminals of the solu-bridge and plug the line cord into a 110-v a-c outlet. Turn the switch to ON, and allow the instrument to warm up for 1 min.

3. Clean the cell by moving it up and down several times in distilled water. Measure the temperature of the sample to be tested, then set the point of the solu-bridge temperature dial to correspond to the thermometer reading.

4. Place the cell in the cylinder containing the 50-ml sample. Move the cell up and down several times under the surface to remove air bubbles inside the cell shield. Immerse the cell until the air vents on the cell shield are submerged.

5. Turn the pointer of the solu-bridge upper dial until the dark segment of the tube reaches its widest opening.

6. Calculate the result in ppm by multiplying the dial reading either by 0.9 or by a factor recommended by local instructions. For example, if the dial reading is 4,000 micromhos and the factor used is 0.9, then 4,000 x 0.9 = 3,600 ppm.

7. Record the results of the test as ppm.

LOCKOUT DEVICES

A lockout device is a mechanism or arrangement that allows the use of key or combination locks (most commonly padlocks) to hold a switch lever or valve handle in the "off" position. Some switches and valves have lockout devices built in; others require modification before locks can be used. As a UT, you may use lockout devices in various situations that involve working on potentially hazardous equipment, such as high pressure steam lines, electrically operated equipment, and boilers. The use of a lockout device is a great advantage since the machine or equipment cannot be started up, energized, or activated while you are working on it. The photos in figure 16-13 will give you an idea of how devices may be used in locking out valves.

MULTIPLE-LOCK ADAPTER

It is often an advantage that a lockout device be capable of accommodating more than one padlock. In that way if you are working on a machine or equipment and have the valve locked "off", then another man can come along and use his padlock so that he can also do hazardous work on the machine or equipment at the same time—rather than wait until you are finished.

Since most controls are not designed to accommodate more than one padlock at a time, multiple lock adaptors (variously called lockout clamps or tongs) are used. (See fig. 16-14.) These adapters should be permanently chained

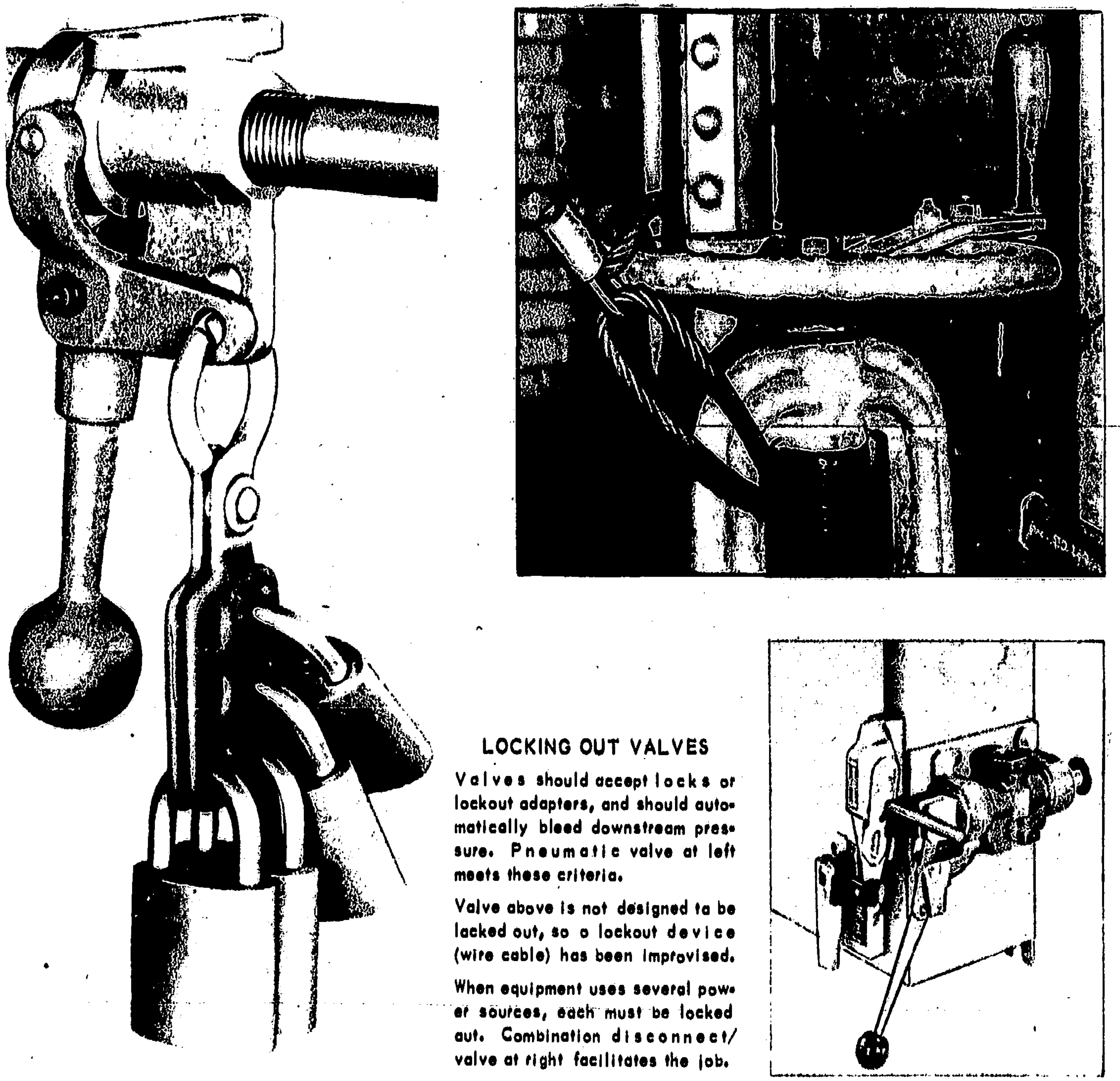

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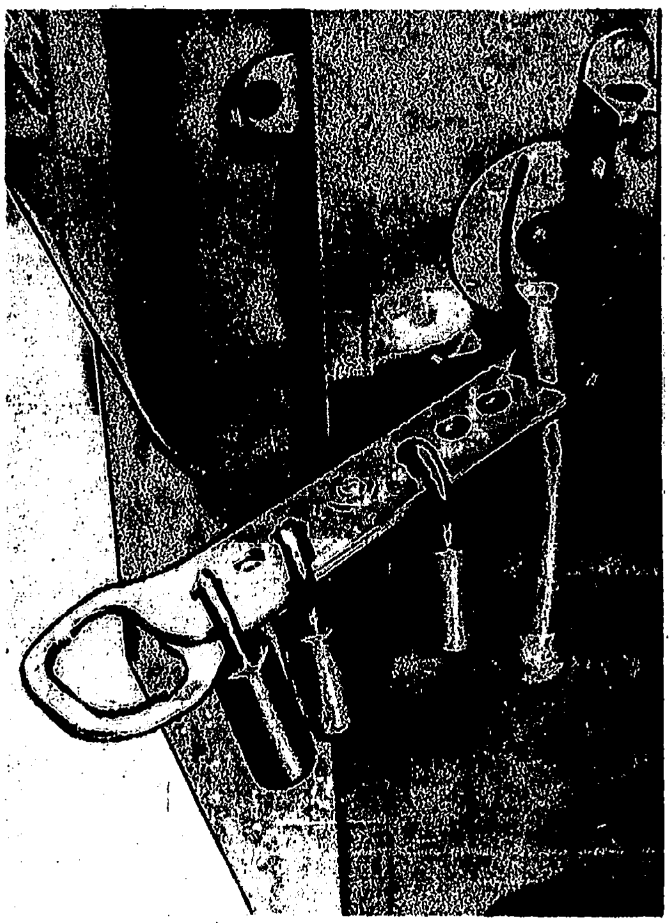
Figure 16-13. — Locking out valves.

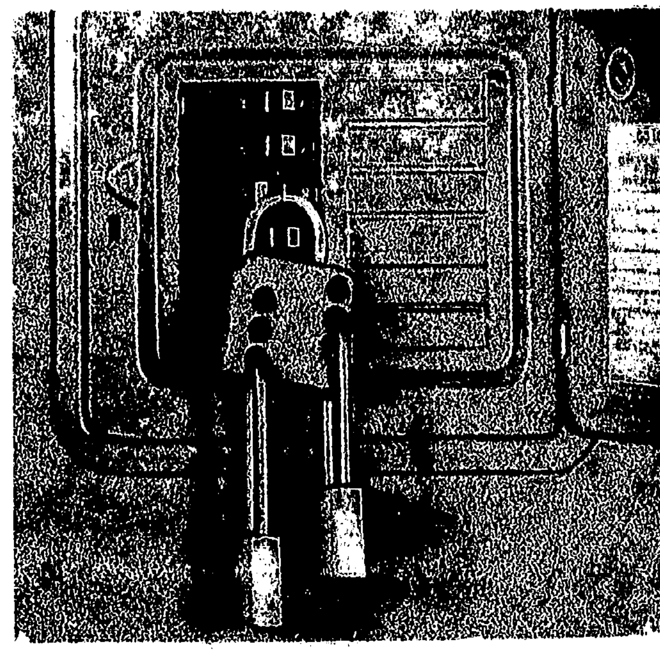
to the control, or, alternatively, issued to all men who have padlocks.

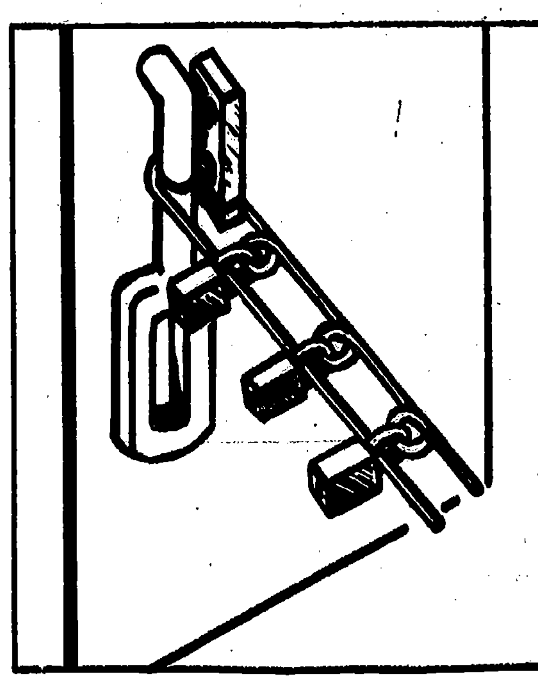
THE LOCKS

Perhaps you are wondering what kind of lock should be used, key or combination? Which person should have a lock? Who should be in possession of keys or combinations? How should the lock be identified? The answers to these questions may vary from one activity to another, but some guidelines are presented below.

1. Key-operated padlocks are more commonly used than combination locks. A main reason for this probably is that supervisors can exercise control over keys easier than combinations.







MULTIPLE LOCK ADAPTERS

Multiple lock adapters allow several padlocks to be used on the same switch lever or valve handle. They are variously called "lockout clamps," "lockout tongs," and "lockout scissors." The photo above shows typical tong-type adapter on switchbox lever.

At upper right, a hasp-type adapter accommodates two locks that guarantee flip-switch will remain "off" until last man has finished his work.

Diagram at right illustrates a shop-made multiple lock adapter formed of 3/16-inch steel wire. Could be designed to take any number of locks.

54.284X

Figure 16-14. — Multiple lock adapters.

2. Locks should be issued to every person who works on closed-down equipment. No key (or combination) should fit more than one lock.

3. Only one key should be issued to a person authorized to use the lock. At some activities, the supervisor may be permitted to maintain a duplicate of keys for locks under his control, or a master key. Some activities, however, may have only one lock-one key. In an emergency, bolt cutters may be used to remove a lock. As a word of caution: KEYS AND LOCKS SHOULD NEVER BE LOANED.

4. Locks should identify the user by name, rate, and shop. This information can be stamped into the lock case, stenciled on, or carried on a metal tag fixed to the shackle of the lock. In addition, locks may be color coded to identify the lock-holder's skill or rating — such as UT, CE, or CM. The colors could follow the hard hat color code.

LOCKOUT PROCEDURE

If locks, lockout devices and multiple-lock adapters are to serve their intended purpose, they must be properly used on every occasion where needed. Make sure that you follow the steps of the lockout procedure below.

1. Before any equipment is locked out, there should be agreement as to the specific machine or unit to be taken out of operation. It is recommended that the supervisor oversee lockout procedures.

2. Turn off the point-of-operation controls. (Remember that disconnect switches should never be pulled while under load, because of the possibility of arcing or even explosion.)

3. See that the main power controls (switch, breaker, or valve) are turned "off." Where electrical voltages are involved, DO NOT attempt this yourself but have it done by a CE.

4. After the switch has been opened or the valve closed, the person (or persons) who will be doing the work snap their locks on the control lever or multiple-lock adapter. At this point, it is good practice to tag the switch, valve, or device being locked. Tags should indicate the type of work being done, approximately how long the job will take, and name of supervisor.

5. Try the disconnect or valve to make sure it cannot be moved to "on."

6. Try the machine controls themselves, as a test that the main controls are really "off."

7. As each person completes his work, he removes his own lock and supplemental tag. The person removing the last lock should notify the supervisor that the work is finished and the equipment is ready to go again.

SAFETY

When it comes to duties involving the operation of servicing of boilers, the need for SAFETY cannot be over emphasized. Much progress has been made over the years in the development of safety devices for boilers. There are still many ways, however, in which serious accidents can happen around boilers. A boiler operator or serviceman who is careless in the performance of his job poses a threat not only to his own safety, but to the safety of others. It seems that accidents somehow have a way of happening at a moment we least expect. All the more reason, therefore, for constant alertness and close attention to detail. Don't take chances! BE SAFETY CONSCIOUS!

Some of the major safety precautions to be observed by UTs engaged in boiler operation and servicing are presented below.

As protection against toxic or explosive gases, boiler settings must be ventilated completely and tested for the presence of toxic or explosive gases before crews are permitted to enter.

The covers of manholes must be removed for ventilation purposes before men enter the drum.

Before men enter steam drums, mud drums, or other waterside enclosures, steam and feed lines connected to the headers under pressure should be isolated by a stop valve and a blank with an open tell-tale valve in between, or by two stop valves with a tell-tale valve opened in between.

A ventilating fan should be operated in the drum when a man is working in the boiler.

Workers should not be inside the waterside of the boiler when pressure is being applied to test a valve which has not been under pressure.

Workers should wear protective clothing when making boiler water tests.

Boiler settings must be examined daily for external air leaks. Cracks, blisters or other dangerous conditions in joints, tubes, seams, or blow-off connections are to be reported to your senior chief petty officer immediately.

Boilers should also be examined regularly for deposits on their heating surfaces and for grease or other foreign matter in the water. Boilers showing any such irregularities should be cleared at the first opportunity and should not be used until cleared.

Performing certain adjustments and repairs while pressure is up is prohibited. A complete absence of pressure is to be ensured by opening the air cock or test and water gage cocks connecting with the steam space before fittings or parts subject to pressure are removed or tightened, and before manhole or handhole plate-fittings are loosened on a boiler which has been under pressure.

Combustion control, feed control, and burner, stoker, or similar adjustments are permitted with the boiler steaming, recognizing that many adjustments can only be made when pressure is up.

When performing cleaning operations, workers should wear the proper personal protective equipment. The following requirements apply:

1. Hard hats and goggles must be worn.

2. When a worker is chopping slag inside a furnace, a respirator must be worn.

3. Safety-toe shoes or toe-guards must be worn to prevent injuries from falling slag.

When a man is working inside the furnace, a large warning sign, such as CAUTION — MAN WORKING INSIDE, should be placed near the furnace entrance.

The use of open-flame lights is prohibited in boilers. When cleaning where flammable vapors and gases may be present, workers are to use only explosion-proof portable lamps equipped with heavily insulated 3-wire conductors, with one conductor connecting the guard to the ground.

Any oil which has accumulated on furnace bottoms should be cleaned out immediately.

The fuel-oil suction and discharge strainers should be cleaned at least every 8 hours, and more frequently if necessary.

Condensate pits in boiler rooms should be provided with metal covers. Where it is necessary that such pits be open for maintenance, adequate guards should be placed around them and warning signs posted.

Wear goggles with dark lenses, number 1.5 to 3 shade, and suitable fireproof face shields when working near or looking through furnace doors of boilers in operation.

When firing a cold boiler, be sure that the air vents are open on the boiler proper and that the drains are open on the superheater; these should be kept open until steam is liberated from the openings. Superheater vents must remain open until the boiler is on the line.

Be sure that gas-fired and oil-fired boilers, whether manual or automatic, are cleared of combustible gases after each false start.

All semiautomatic (multi-burner) boilers and all fully automatic boilers should be equipped with a manually activated switch for pilot ignition and a control device to prove the pilot flame before the main fuel valve is opened. DO NOT USE A HAND TORCH TO LIGHT OFF A BOILER. If a hand torch is applied to a firebox filled with vaporized oil, a severe boiler explosion is likely to result.

Prevent overheating of boilers equipped with superheaters by firing at a slow rate during the warm-up period and allowing a small amount of steam to flow through the superheater.

When taking over a watch, blow the water gages and note the return of the water in the glass. Be certain of the water level at all times. DO NOT be misled by a dirt marking on the gage which may look like the surface of the water. DO NOT depend entirely upon automatic alarm devices and automatic feed-water regulators.

If the water goes out of sight in the bottom of the gage glass, kill the fire, utilizing the quickest means available, immediately close the steam stop valve, and allow the boiler to cool slowly; then drain the boiler completely and open it for inspection. DO NOT FEED COLD WATER TO A BOILER THAT HAS HAD LOW WATER UNTIL THE BOILER HAS COOLED.

Check the water on steaming boilers by try cocks at least once each watch and before connecting a boiler to the line.

Blowdown the water glasses before connecting a boiler to the line. Remember that a fall in steam pressure may indicate low water.

Check safety valves at frequent intervals to be sure they will pop at the correct pressure, as marked on the nameplate. DO NOT break the seal of a safety valve or change its adjustment, unless such action has been authorized. NEVER weight pop valves, relief valves, and so on, to increase the recommended steam pressure for which the boiler is approved.

Do not use oil from a tank in which a considerable amount of water is mixed with the oil unless a high suction connection is provided. When an atomizer sputters, shift the suction to the stand-by tank or another storage tank. A sputtering atomizer indicates water in the oil.

Minimize the fouling of oil heaters by using as few heaters as possible. Recirculate the oil through the used heaters for a short time after securing the burners. Maintain the prescribed fuel-oil temperature; DO NOT exceed it.

If a large steam leak occurs in a boiler, shut off the burners, continue to feed water until the fire is out, close the steam stop valve, ease the safety valves, clear the furnace of gases, close the registers, and cool the boiler slowly.

DO NOT tighten a nut, bolt, or pipe thread, nor strike any part, nor attempt to make any other adjustments to parts while the boiler is under steam or air pressure.

Exercise precautions to prevent lubricating oil, soap, or other foreign substances from getting into the boiler. Condensate from cleaning vats should be drained to waste and not returned to the boiler.

Close the furnace openings as soon as all fires have been extinguished and the furnace has been cleared of gases.

At shore installations the handles on pull chains to boiler water-gage cocks and water-gage glass stop valves should be painted the following colors:

Opening water-gage glass stop valves	WHITE
Closing water-gage glass stop valves	RED
Top gage cock	YELLOW

Center gage cock	GREEN
Bottom gage cock	BLUE

DO NOT use water to extinguish an oil fire in the furnace.

When fires are banked, make certain the draft is sufficient to carry off flammable gas accumulations.

In case of an oil fire in the boiler room, close the master fuel-oil valve and stop the oil pump.

In addition to the above precautions, the following list contains a number of SAFE practices which you should endeavor earnestly to follow in your work. It also contains a number of UNSAFE practices which you should make a vigorous effort to AVOID.

NEVER	ALWAYS
Never fail to anticipate emergencies. Don't wait until something happens before you start thinking.	Always study every conceivable emergency and know exactly what moves to make.
Never start work on a new job without tracing every pipeline in the plant and learning the location and purpose of each and every valve regardless of size. Know your job!	Always proceed to proper valves or switches rapidly but without confusion in time of emergency. You can think better walking than running.
Never leave an open blowdown valve unattended when a boiler is under pressure or has a fire in it. Play safe, memory can fail.	Always check water level in the gage glass with the gage cocks at least daily—also at any other time you doubt the accuracy of the glass indication.
Never give verbal orders for important operations or report such operations verbally with no record. Have something to back you up when needed.	Always accompany orders for important operations with a written memorandum. Use a log book to record every important fact or unusual occurrence.
Never light a fire under a boiler without a double check on the water level. Many boilers have been ruined this way.	Always have at least one gage of water before lighting off. The level should be checked by the gage cocks.
Never light a fire under a boiler without checking all valves. Why take a chance?	Always be sure blowdown valves are closed, and proper vents, water-column valves, and pressure-gage cock are open.
Never open a valve under pressure quickly. The sudden change in pressure, or resulting water hammer, may cause piping failure.	Always use the bypass if one is provided. Crack the valve from its seat slightly and await pressure equalization. Then open it slowly.
Never cut a boiler in on the line unless its pressure is within a few pounds of header pressure. Sudden stressing of a boiler under pressure is dangerous.	Always watch the steam gage closely and be prepared to cut the boiler in, opening the stop valve only when the pressures are nearly equal.
Never bring a boiler up to pressure without trying the safety valve. A boiler with its safety valve stuck is nearly as safe as playing with dynamite.	Always lift the valve from its seat by the hand lever when the pressure reaches about three-quarters of popping pressure.
Never increase the setting of a safety valve without authority. Serious accidents have occurred from failure to observe this rule.	Always consult the CEC officer in charge of the plant, your CPO, or other proper superior and accept his recommendations before increasing the safety-valve setting.

NEVER	ALWAYS
Never change adjustment of a safety valve more than 10 per cent. Proper operation depends on the proper spring.	Always have the valve fitted with a new spring and restamped by the manufacturer for changes over 10 percent.
Never allow unauthorized persons to tamper with any steam-plant equipment. If they don't injure themselves, they may cause injury to you.	Always keep out loiterers, and place plant operation in the hands of proper persons. A boiler room is not a safe place for a club meeting.
Never allow major repairs to a boiler without authorization.	Always consult the CEC officer in charge of the plant, your CPO, or other proper superior before making any major repair to a boiler.
Never attempt to light a burner without venting the furnace until clear. Burns are painful.	Always allow draft to clear furnace of gas and dust for several minutes. Change draft conditions slowly.
Never fail to report unusual behavior of a boiler or other equipment. It may be a warning of danger.	Always consult someone in authority. Two heads are better than one.

CHAPTER 17

GALLEY AND HEATING EQUIPMENT

This chapter provides basic instruction concerning the installation and maintenance of common types of galley equipment, immersion can heaters, and oil-fired space heaters. A brief treatment also is presented on fire prevention—including classes of fire and fire-fighting equipment.

Due to differences in types of equipment that you will be installing and maintaining, only general information, which will apply in most cases, willl be presented here. Remember that the manufacturer's manual that accompanies a new piece of equipment should be studied carefully prior to installation or maintenance of a particular unit.

With space being limited, remember also that this discussion does not cover roughing-in, which is a necessary step prior to the installation of various kinds of equipment. Before the installation of coppers, for instance, deck drains must be provided and water and steam service lines must be roughed-in. Information on roughing-in is presented in chapter 4, as part of our instruction in plumbing.

GALLEY EQUIPMENT

The installation and maintenance of galley equipment must be performed in a way that will ensure safe, sanitary, and economical operation. Utilitiesmen not only install and maintain this equipment themselves, but also supervise lower rated men in the performance of this work. It is good practice that operational instructions be posted at the various pieces of equipment in the galley or bakeshop to ensure that the operators will not abuse the machines; this is especially important where messmen and strikers are working. As a further safeguard, conduct periodic preventive maintenance (P/M) inspections, as required for the equipment at your particular location—or as called for in the manufacturer's instructions. It is advisable to attach to individual pieces of equipment a tag o. which is recorded pertinent information—such as the date and type of inspection and by whom made.

The installation and maintenance of food preparation equipment may vary in nature. In peacetime, most all types will be in a permanent galley or bakeshop. While operating in a construction battalion deployed for the purpose of construction and/or training to an island or an overseas shore station, the battalion might either have a permanent galley or a semi-permanent galley—using either field units or fixed-type equipment. In a time of disaster, hurricane, flood or fire, SEABEES may be called upon for assistance. In such cases, field units—of the same type employed in combat zones—are used for preparing food. Whatever the need or the location, the important thing is to keep all equipment in a condition of readiness that ensures safe, sanitary, and excellent operation at all times. Major factors concerning some of the common types of galley equipment are given in the following subsections.

COPPERS

Steam-jacketed kettles are often called COPPERS by Commissarymen, so we will refer to them as such in this discussion. A point to note, however, is that they are constructed of corrosion-resisting steel, aluminum, or single clad corrosion-resisting steel (not copper). Coppers vary in size from 20 to 80 gallons, and are used for boiling food without live steam coming into direct contact with the food. A jacket around the lower part of the copper allows steam to circulate between the jacket and the inner shell, thus heating the contents. Figure 17-1 shows several coppers which have been installed and are ready for use.

A hinged lid helps prevent the escape of heat out the top and serves as a cover for the food. Coppers are fitted with draw-off faucets,

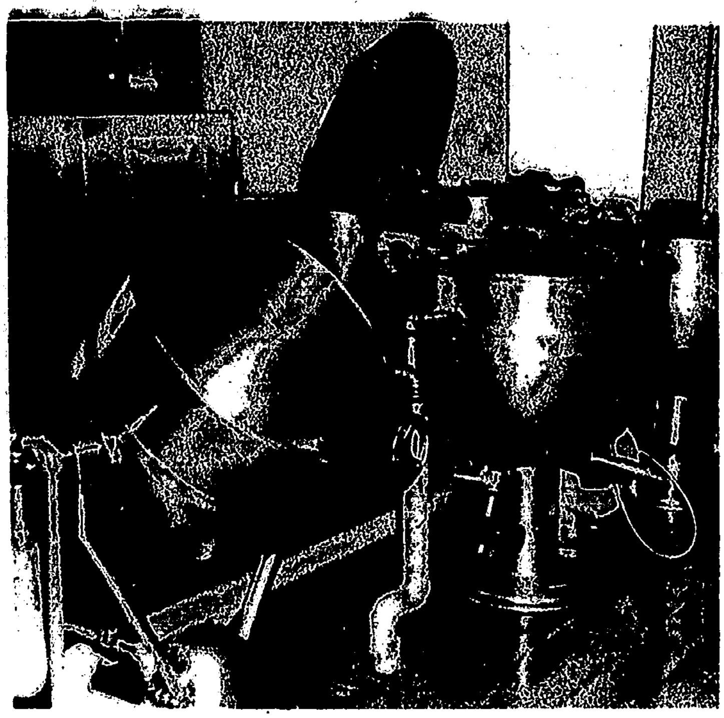


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Figure 17-1.—Coppers.

so the unit may also be used as a coffee urn. A special copper which can be tilted often is used in bakeries and galleys. With this type, heavy materials may be tilted to drain off materials.

Installation

Installation of coppers should be in a depressed floor area or behind a curb wall, if possible. The unit should be bolted securely to the floor. The steam supply piping should be the full size of the equipment inlet fitting, and the supply line should be fitted with a pressure reducing valve. Too, a steam control valve should be located near the copper for the convenience of the operator.

The steam supplied to coppers for service connections is reduced in pressure to approximately 40 pounds. Connect the condensate return line to the steam outlet connection. Then install a suitable steam trap in the condensate return line near the copper. In the cold water supply line, install a globe valve and leave an air gap between the top of the copper and the water service line.

Maintenance of Coppers

As a Utilitiesman, you may often be called upon to assist in making inspections of galley equipment to determine the type of maintenance and extent of repairs (if any) required to keep the equipment in safe, efficient operating condition. To avoid exceeding your authority, remember that the medical department is responsible for conducting sanitary-type inspections and the supply department is responsible for preparing food and keeping food-handling equipment and spaces clean.

Coppers require minimum monthly and annual preventive maintenance inspections. A few factors to consider in inspecting direct-steam connected types of coppers are given below. Incidentally, The Navy also uses a gas-fired type of copper but, with space being limited, we are primarily interested here in the direct-steam connected type.

When making a MONTHLY inspection, check the draw-off faucets, valves, and piping to ensure there are no leaks. Check the steam pressure reducing valve to see that it is in good condition and functions properly, and lubricate the hinges of the cover with mineral oil.

In the ANNUAL inspection, check the copper for leaks, cracks and dents. Examine the cover, hinges, and latch for warp and alignment. Check the steam and condensate piping, valves, and traps for leaks and obstructions. Remove the safety valves; then clean, lubricate, and calibrate them before replacing. Remove rust and corrosion, if present, using Navy-approved solvents.

In addition to visual inspections, each individual piece of galley equipment requires its own type of preventive maintenance. In table 17-1 is a recommended schedule for the inspection and maintenance of the coppers and other steam heated equipment.

STEAM CHESTS

A steam chest, such as that installed in a modern Navy galley, is similar to the pressure cooker used in private homes. It is designed to cook food with live steam, under pressure, coming into direct contact with the food being prepared. (See fig. 17-2.) In a galley the steam is supplied from an outside source, and usually is connected on the same steam line as the coppers. This type is called a direct-connected steam chest or vegetable steamer and is the type we are concerned with here, since it is more commonly used by the Navy.

Table 17-1. —Inspection and Maintenance of Coppers and Other Steam Heated Equipment

Inspection Point	Symptoms	Time	Possible Troubles/Causes	Possible Corrections
Steam jacket	Not heating	When noted	No steam; valve stuck closed; trap malfunctioning	Check steam supply; free stuck valve
Steam jacket	Stays hot	When noted	Valve partly open or scored seat	Repair or replace valve
Steam jacket	Leaks	Monthly	Rapid changes in temperature causing cracks; faulty weld	Raise heat slower; reweld bust or crack
Pipe joints	Leaks	Monthly	Joint made incorrectly; not tight	Unscrew, clean and repair joint
Pipe joints	Corrosion	Monthly	Leaks or condensation	Repair and/or clean
Control valves	Stuck open or closed	When noted	No steam or too much steam; packing too tight or valve frozen	Loosen packing gland or free frozen valve stem
Control valves	Leaks at stem	Weekly	Packing not tight enough	Tighten packing.
Condensate strainer	No flow	When noted	Restricted strainer	Clean strainer
Steam trap	Malfunctioning	Every 6 months	Parts dirty or worn	Disassemble, clean, and repair
Lagging	Broken or crushed	Quarterly	Water soaked; stepped on	Replace defective sections
Reducing valve	Incorrect pressure	When noted	Parts dirty or worn	Disassemble, clean, and repair; clean and adjust pressure every 6 months
Safety valve	Stuck open or lifting under pressure	When noted	Leaks or corrosion	Replace or repair valve
Covers	Tight operation	When noted	Hinges dirty	Clean and lubricate hinges
Draw-off valve	Leaks	When noted	Scored	Resurface or replace. DO NOT REPLACE WITH REGULAR GATE VALVE

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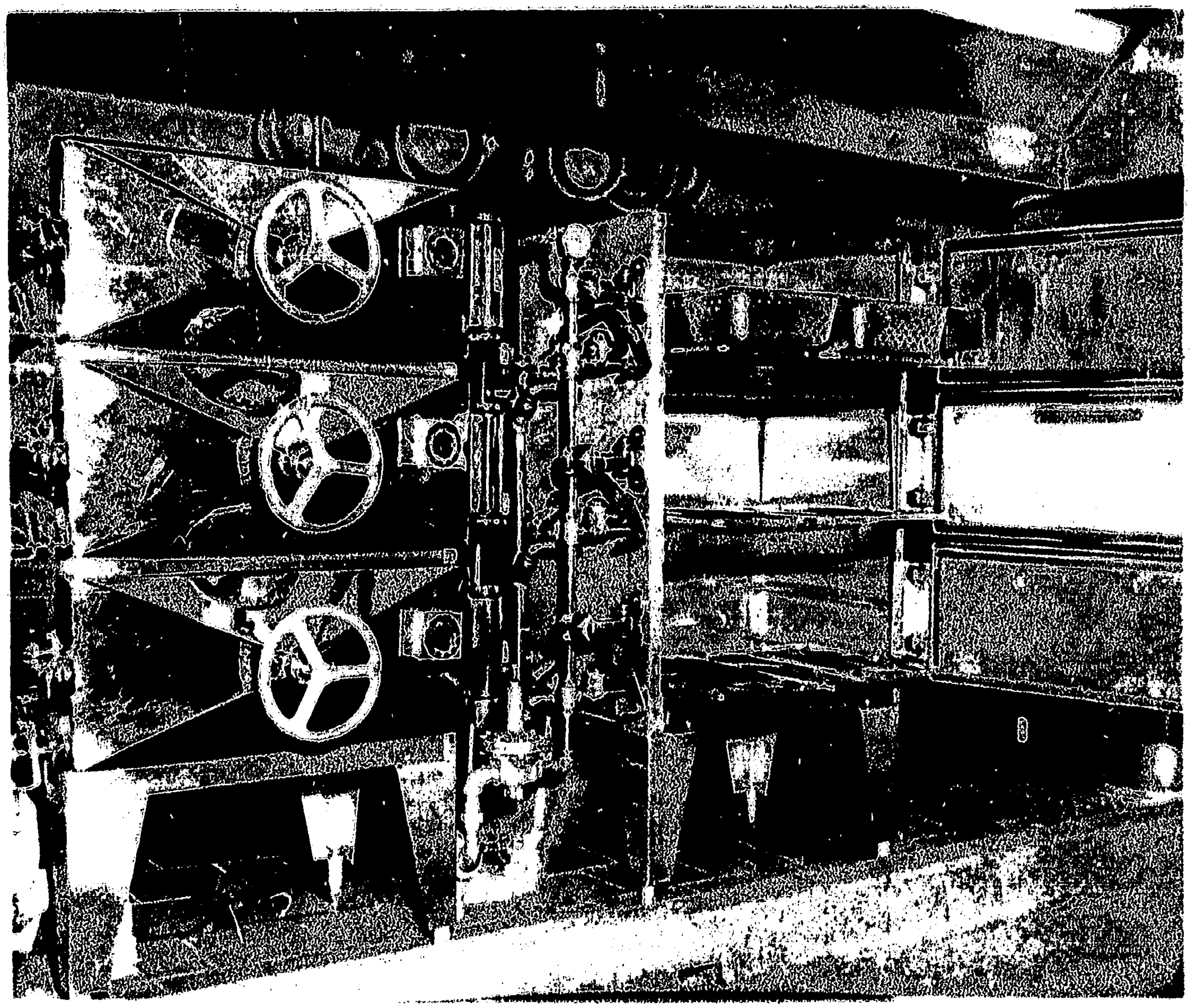

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Figure 17-2.—Direct-connected steam chests.

Installation

When installing a direct-connected steam chest, place it in line or near the coppers to facilitate installation and cooking operations. Be sure the unit is near a floor drain. This arrangement will permit compartment drips and drains to discharge without wetting the surrounding floor area.

Set the steam chest in a level position, using the adjusting bolts on the feet. As an aid to leveling, pour a small amount of water into one compartment and adjust the legs so that water drains through the drain opening. DO NOT MAKE A SOLID CONNECTION FROM THE BLOW-OFF VALVE TO THE DRAIN PIPING.

When steam is connected to the steam chest a pressure reducing valve will have to be installed, reducing the steam to a pressure of about 7 pounds per square inch (psi) or less, as recommended by the manufacturer. For safe operation, set the safety valve to open just above the reduced pressure.

Maintenance of Steam Chests

The escape of steam from steam chests is detrimental to the food being prepared. It also poses a safety hazard to personnel. A main step towards ensuring steamtight operation is to see that the door latches, hinges and gaskets are maintained in a close-fitting condition.

A physical preventive maintenance inspection of the steam chests should be made each week. As part of this inspection, make sure the compartment drains are free of obstructions; that the door hinges, locking devices, and shelf drawbars are in good operating condition; and that the pressure setting of the gage pressure is correct.

If a plunger-type valve is used with the locking device, the plunger must be adjusted so that the valve is fully depressed, when the door is closed; this allows the full complement of steam to enter the compartment. When the door is opened, the valve must function to completely stop the steam supply.

To ensure a tight fit of the doors, replace hinge pins and bushings when they become excessively worn. Some full-floating doors are adjustable by means of hexagon-head bolts extending through the door near each corner. When gaskets must be replaced, remove the door from the unit. It will then be easier to remove the worn gasket, and to clean the channel, since not to do so would provide a path for possible steam leakage. Apply gasket cement, and then force the new gasket into the channel at the corners, working it in towards the center of the sides and ends. You are now ready to rehang the door; but first place paper along the edge of the door opening to prevent excess cement from adhering to the mating surfaces when the door is closed. Any surplus cement can be cleaned off after it has hardened.

If the door has hexagon-head bolts, adjust them so that the closed door touches the steamer evenly, without binding at the corners. Unless you have a good fit, the gasket will be cut by the corners of the door and steam will escape.

For inspection and preventive maintenance of the steam service and condensate system, include those items that apply in table 17-1.

STEAMTABLES

Steamtables are placed along the food serving line. They are used to keep food brought from the kitchen area hot during the serving period. Steamtables may be equipped with various types of heating units, such as steam coils, electric elements, or gas burners. The steam-coil type is widely used by the Navy. Steamtables come in many different styles and sizes. But construction is basically the same for all units. Figure 17-3 illustrates a schematic drawing of a typical steamtable.

Steamtables are constructed of corrosion-resistant, light gage steel. The steam-heated

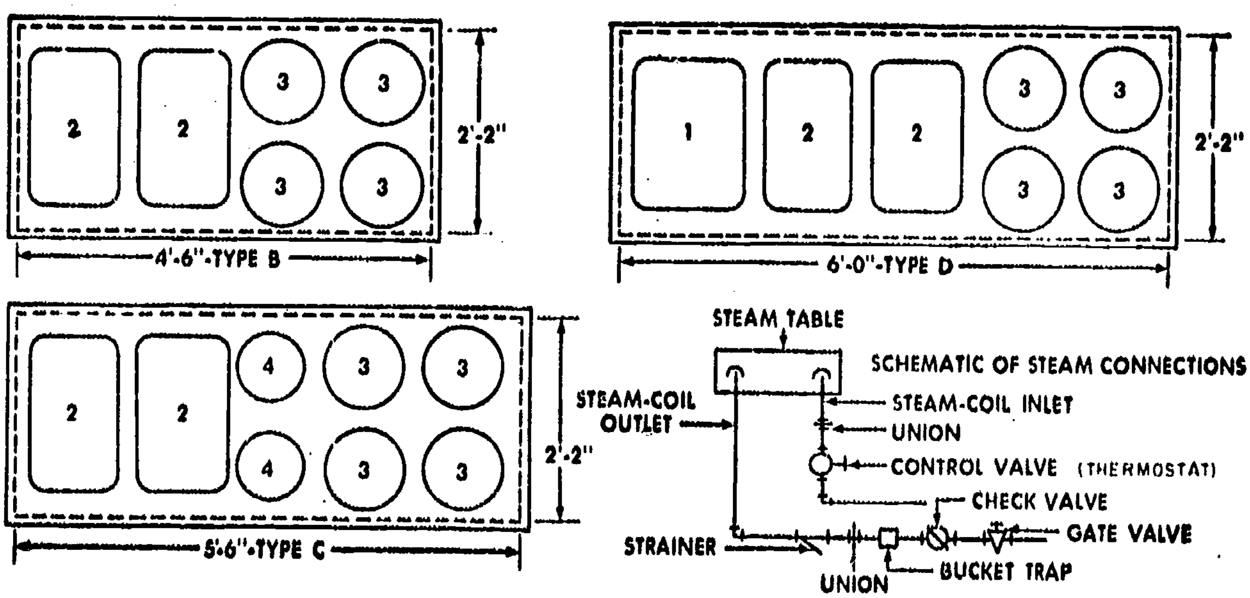

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Figure 17-3. —Schematic drawing of a steamtable.

type, which we will discuss here, has a steam-coil inlet, control valve, and pressure regulating valves on the inlet side. The outlet side is fitted with a strainer, bucket trap, check valve and gate valve. In addition, most steam-tables are fitted with a waterline, which is used to fill the water compartment.

Around the galley you may often hear the term "bain-marie." We should explain, therefore, that the bain-marie, is used in the galley near the cooking units, its purpose being to keep food that has been cooked warm until needed on the serving line. Briefly stated, steam-tables and bain-maries serve the same basic purpose, but are named differently depending upon the location (that is, serving line or galley) where installed.

Installation

When installing a steamtable, locate the unit on the floor in the desired area, making sure that

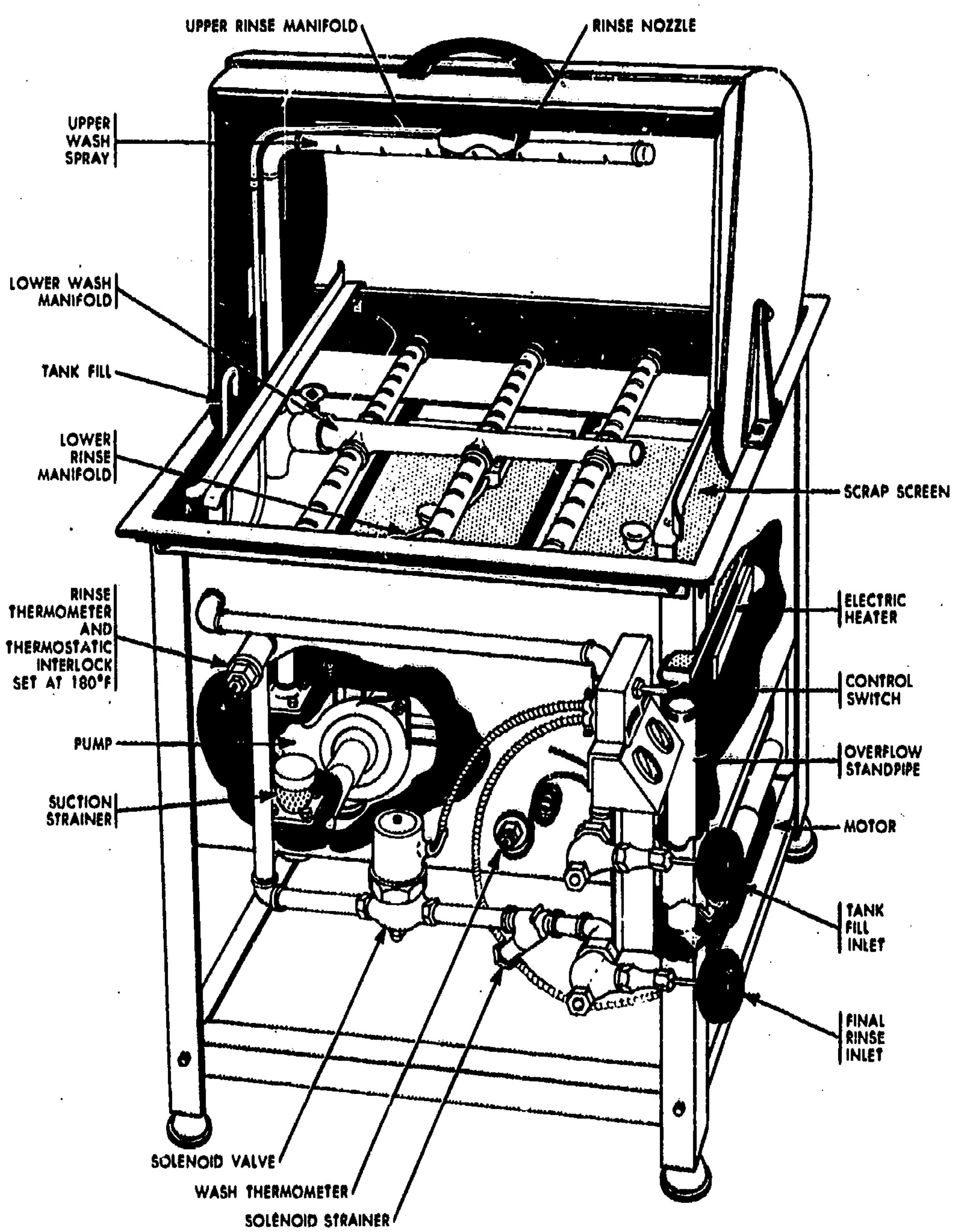

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Figure 17-4.—Semiautomatic single tank dishwasher machine for use in small messes.

a level and firm foundation is provided. Be sure the bottom of the water compartment "grades" or slopes towards the drain outlet to permit complete drainage of water from the compartment when desired.

An indirect waste connection is required to discharge over a floor drain. Connect the water supply line to the equipment connection. Connect the steam supply and condensate return line. Following the manufacturer's instructions, adjust controls to the prescribed temperature and pressure setting.

All steam and hot water piping should be insulated whenever there is a possibility of personnel exposure to burns. Information on insulating is given in chapter 4.

Maintenance of Steamtables

Steamtables should be carefully inspected on a monthly and yearly basis. In making a monthly inspection, check the water compartment, steam coil, valves and piping for leaks and corrosion. Check the steam pressure on the gage, keeping in mind that PRESSURE

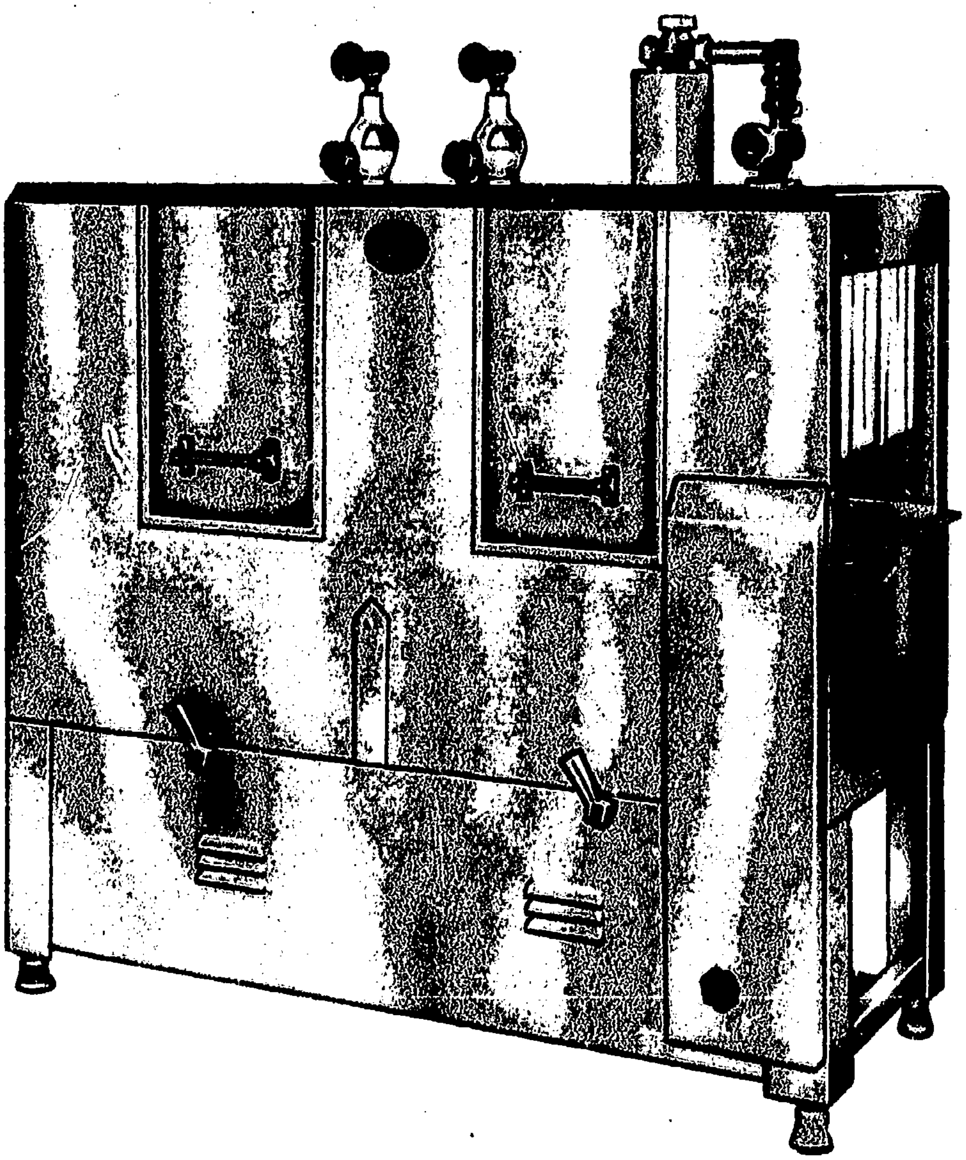

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Figure 17-5.—Automatic double-tank dishwasher for large messes.

SHOULD NOT EXCEED MAXIMUM PRESSURE SHOWN ON THE NAMEPLATE. In addition, calibrate the temperature control.

When conducting an annual inspection of steamtables, descale the water compartment, examine the top and frame for scale, and check the level of the steamtable top. Then check the thermostat using a mercury thermometer. The thermostat must be accurate to 5° F plus or minus. Remove rust and corrosion within the water compartment with solvent, and paint bare spots with heat-resistant aluminum paint. Use table 17-1 to check other items, as applicable to this equipment.

DISHWASHING MACHINES

Various types of dishwashing machines are used at Navy activities. Types that you may work with include the single tank, multiple tank, rackless, and domestic dishwashers.

The process of washing and rinsing is semiautomatic in a SINGLE TANK unit. In ordinary single tank units a rack filled with dishes is placed in the machine by hand, and washing and rinsing actions are controlled by a lever which regulates washing, spraying, and rinsing operations. Racks are removed by hand, and replaced with other racks filled with dishes to be washed. A semiautomatic, single-tank dishwasher machine, which is very suitable for use in small messes, is pictured in figure 17-4.

In a MULTIPLE TANK machine, dishwashing is automatic to the extent that the processes of power wash spraying, power rinse spraying, and final rinsing may be carried on concurrently with two trays of dishes. A timing device is set to provide 20 seconds of washing and 10 seconds of rinsing. After a rack filled with soiled dishes has been washed, it slides automatically to the rinse compartment, in which water of at least 180° F temperature is required. While the first rack of dishes is being rinse sprayed, the second rack of dishes is being washed. After a rack is pushed from the wash to the spray compartment, another rack of

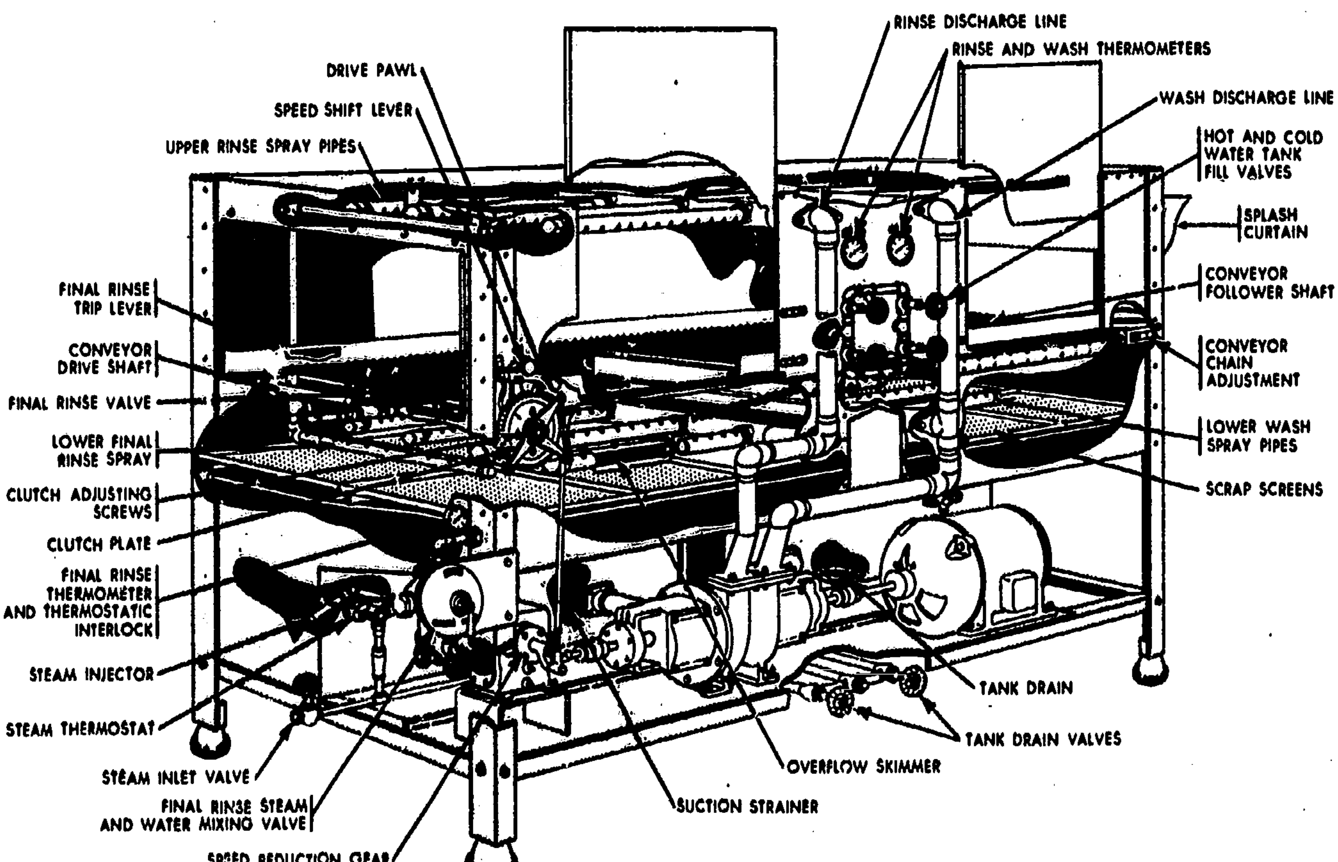

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Figure 17-6.—Cutaway view of double-tank automatic dishwasher.

soiled dishes is placed by hand in the washing compartment. (See figs. 17-5 and 17-6.)

You may hear the RACKLESS type of dishwasher sometimes referred to as the FLIGHT type. These dishwashers are provided in single- and in multiple-tank units. The sequences of washing are much the same as in ordinary tank units, but the dishes are passed through the washing and rinsing compartments on a conveyor belt instead of in racks or trays. The loading section is located on one side of the machine, and the unloading section on the opposite side. An endless conveyor belt travels the entire length of the machine. The belts are usually made of stainless steel and nylon, and some belts are provided with upright, nylon-covered pegs, which hold the dishes in place. The belt is provided with an automatic stop mechanism to prevent any damage to dishes or glasses if they are not removed before reaching the end of the unloading section of the machine. The belt is geared to move at a rate of speed which allows sufficient time for each dish or glass to be thoroughly washed and rinsed.

The DOMESTIC dishwasher is provided as a separate unit, or as part of a kitchen sink combination. It has similar features to that of a single-tank dishwasher. In most models, two racks filled with dishes are placed in the machine by hand, and its actions are controlled by the setting of a dial. This dial regulates the periods of time for washing, spraying, and rinsing operations. Automatic dispensers control the supplies of detergent and wetting agents during the appropriate washing and rinsing phases. Some models are equipped with safety interlock switches, which automatically shut off the current and stop all action if the door is accidentally opened.

Installation of Dishwashers

The following general procedure will serve as a guide when installing dishwashing machines. As the first step, set the dishwasher in position and level the machine. If the machine has adjustable legs, these should be used for leveling. Where adjustable legs are not provided, ten shims may be used to level the unit.

Connect the hot water inlet to the hot water line, using the proper fittings for the particular make and model of machine being installed. Water supplied must be at least 180° F or a booster-type heater will have to be installed. Connect the cold water inlet to the machine; this is used to temper the water in the washing side of the machine. The pipe sizes will vary according to the machine and fittings used. Follow the drawings and specifications for the hook up of the machine concerned, as only general information is covered here.

Install a steam supply line of proper size from the main steam line to the dishwasher. Then install a steam trap on the condensate return line. Be sure the steam trap is of the PROPER SIZE and designed for the steam pressure available. Pipes should be insulated (or lagged), as required; information on lagging is presented in chapter 4 of this training manual.

The use of tables on each end of the dishwasher provides a much-needed convenience for the operators. When installing these tables, it is well to fit the ends of the tabletops over the lip of the dishwasher to ensure a watertight connection and smoother operation.

The tables should be lined up carefully with the rack tracks, and then bolted to the dishwasher. See that the tabletops are level with the rack tracks. Use gaskets or metal shims to compensate for variations in thickness of the tabletops. Fit the soiled-dish end of each table with guide blocks or side flanges to guide racks onto rack tracks in the dishwasher.

Bolt the tables to the rim of the dishwasher, using countersunk screws or suitable bolts, or weld to the rim of the dishwasher under the tabletop. If you have a choice, use bolts and soft washers to prevent leaking. The use of bolts and washers will be an advantage, of course, in case it becomes necessary to unfasten or remove the tables at some later date.

Maintenance of Dishwashers

From time to time, you may be called upon to adjust dishwashing machines which have become defective. Some of the most common difficulties, the usual reasons for their occurrence, and possible remedies for them are listed in table 17-2.

Descaling to remove deposits from within the machine, as well as in the piping and pumps, must be done periodically. This can be accomplished by filling the tanks half-full with hot water, adding an approved cleaning solution, filling the tanks to overflow, and then operating the machine for 30 minutes, at high temperature, and with the trays, spray arms, and curtains in place.

After this period of operation, drain the tanks and fill them with hot water; then run the machine for 5 minutes. This rinsing procedure

Table 17-2. — Troubleshooting for Dishwashing Machine

Trouble	Probable cause	Possible remedy
Dishracks slide off chain conveyor.	Change of tension on either chain.	Reset idler sprockets to proper tension on each chain.
Water pressure too low.	Spray nozzles or slot plugged. Strainer baskets plugged. Slipping belts on pumps.	Dismantle spray assembly. Wash out piping, clean parts. Disassemble and clean strainer. If belts are frayed or torn, replace them. Adjust tension by resetting idler pulley or by moving motor on sliding base.
Water splashing on floor or into wrong compartment.	Leaks around doors, torn curtains or curtains not in proper position.	Realign door. Repair or replace gasket. Repair or realign curtain. Readjust spray to keep it within limits of tank.
Rinse water temperature is less than 180° F.	Insufficient heat from booster heater.	Remove scale from steam coil. Correct leaking fittings. Adjust gas burners. Calibrate or replace thermostat.
Spots or film on eating utensils after final rinse.	Wash water saturated with grease. Dirty tank. Weak sprays in wrong position. Improper detergent mixture.	Stop operation and clean all equipment. Adjust speed of conveyor. Examine spray equipment. Clean nozzles, spray pipes, scrap trays, and strainers. Check piping for leaks. Check to see if valves are operating properly. Examine pump. Clean impeller if necessary.

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should be repeated several times, in order to make sure that all the cleaning solution has been removed.

Dishwashing machines and accessories should be lubricated in accordance with the manufacturer's instructions. This is especially true in the selection of grades and viscosities of oil used, the levels at which the oil is to be maintained, and locations to be oiled. All damaged or missing lubrication fittings should be replaced. The grease cups on the drive end, connecting rod, and the rinse lever should be replaced. The grease cups on the drive end, connecting rod, and the rinse lever should be turned about once each quarter and refilled when empty. The revolving wash arms and valve stems should have a few drops of light oil applied to them about once each quarter.

CAUTION: Extreme care should be taken to turn off the power before lubricating the equipment.

With space being limited, complete details on the maintenance of all parts and accessories of dishwashing machines cannot be given in this training manual. The reader is urged to study the manufacturer's manual for the type and make of machine concerned. A brief treatment on some of the machine parts and accessories which should be maintained and serviced regularly is given below.

1. Repair or replace torn or worn curtains.
2. Straighten warped pans so that they lie flat in the machine.
3. Replace packing with new material of the same kind and size. Do not overpack in the packing gland. This causes binding of the shaft.
4. Replace broken or damaged thermometers. Check the accuracy of the thermometer by measuring the water temperature with a high grade thermometer and comparing results with a thermostat setting. The thermostat should be set for a wash-water temperature of 138° to 145° F and rinse water for a temperature of 180° F or above.
5. Defective conveyors should be properly adjusted or replaced. Check nylon covering of steel parts, and replace them when they are worn or torn.
6. The inspection doors of wash and rinse compartments should be kept tight at all times. Straighten or replace bent or loose doors.
7. Check chains and pulleys of counterbalanced doors. Apply oil regularly to moving parts.
8. Check dish racks for bent or warped surfaces and replace broken parts.
9. Inspect utility fittings, such as steam coils and traps, heating elements, gas burners, and all thermostats. Follow the manufacturer's repair instructions. It is usually necessary to detach these component parts and take them to the maintenance shop for repairs.
10. Ventilating hoods are installed above or at ends of dishwashing machines, and are equipped with fans. By these means, moisture and heated air created by the use of hot water in the machine are collected and exhausted. All surfaces of the hood should be frequently checked for corrosion and rust. Remove rust with solvents and paint over corroded areas with two coats of rust resistant paint. In selecting a solvent, use air inhibited sulfamic acid type according to the manufacturer's instructions. Never use steel wool for cleaning interior surfaces, because small particles may come in contact with dishes and eventually become embedded in food. Check the ventilating fan for collection of grease and other impurities, which should be scraped off with a knife. Fan accessories, such as baffles, dampers, vanes, access doors, louvers, registers, protective grilles, bird or insect screens, should all be checked for rust and corrosion, and corrective action taken. Any of these items which have become loosened by vibration should be tightened, and worn or missing parts replaced.

With regular inspection and lubrication with repairs and adjustments made as necessary, and with strict observance of manufacturer's operating instructions, these machines are capable of a long period of satisfactory service. To make sure they receive the required attention, set up a regular schedule of inspection. Monthly and annual inspections may be satisfactory in most cases.

MONTHLY inspection and maintenance should include the following items:

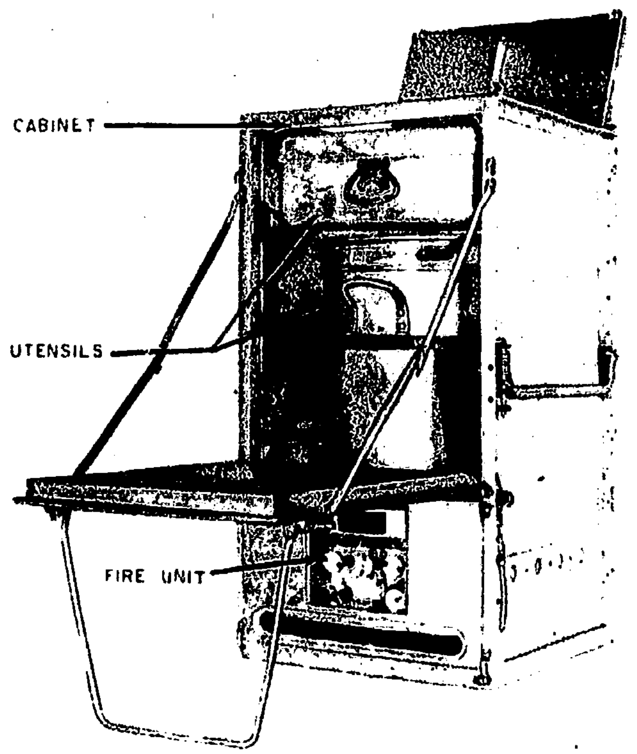
1. Check the lubrication of bearings, gear boxes, chains, and sprockets; lubricants should be added, if required.
2. Check the alignment and tension of drives V-belts, flexible couplings, chains and sprocket.
3. Have an electrician check the electrical components for proper functioning and safety features, including proper grounding of dishwasher.
4. Make a general check on level of machine and tables; check for misalignment of parts, loose parts and leaks, and unusual noises.
5. Check the piping system for faults.

In making an ANNUAL INSPECTION of dishwashers, give careful attention to the following items:

1. Check frames for adequacy of support; tightness of casings, seams, joints, counterweights; evidences of corrosion; watertightness of doors, hinges, gaskets; and correctness of clearance and alignment.
2. Check pumps and impellers for possible corrosion or extreme wear of any of the parts. Disassemble them, clean all parts thoroughly, and repair or replace badly worn parts. Reassemble and adjust. Lubricate all parts requiring lubrication. NOTE: be sure and tag the dishwasher, stating the date of the current inspection, the repairs made, and the date when the next inspection will be due.

RANGES

Most ranges are composite pieces of equipment and may include any combination of units such as a cooking top, oven, broiler, griddle, and deep-fat fryer. They may be heated by electric heating elements, oil burners, or gas burners. Whatever the heating device, it must



48.61
Figure 17-7.—Field range with fire unit in position for cooking.

be maintained in a safe and economical operating condition. Utilitiesmen have various responsibilities involving the installation and maintenance of oil- and gas-fired equipment, so our primary concern here is with these two types. A gas-fired type of field range is shown in figure 17-7.

Installation

When new equipment is received for installation, all the assemblies, subassemblies and accessories must be inspected to see that they are all present, in good condition, and properly assembled. The equipment should be unpacked as near to the site of installation as practical.

To assemble, separate the components and accessories of one complete unit. Follow carefully the manufacturer's instructions; assemble one unit at a time. Seal all joints, cracks, and openings which might permit heat leakage or interfere with proper draft.

When ranges or ovens are installed along a combustible wall or partition, they must be at least 18 inches from the wall. As additional protection, erect a shield of 1/4-inch asbestos board or similar material.

Good VENTILATION of ranges and ovens—including flue connections and room vents—is just as important for proper operation as selecting the correct site. Generally speaking, ovens and ranges should NOT be directly vent connected. The best method of venting three or more pieces of equipment is by means of a hood, which extends 6 inches beyond all sides of the cooking surfaces. The hood should be connected to an adequate exhaust duct.

When a direct flue is installed, an approved draft diverter should be used according to the manufacturer's instructions. In addition to the draft diverter, it is necessary to install an adequately sized automatic draft-check in the flue line as close as possible to the equipment connection.

In regards to safety and best operation, never place steel wool or other obstructions in a flue. Assure that enough air is allowed to enter the room to compensate for air removed by the ventilating system and combustion.

Maintenance

A schedule of monthly and annual inspections is an important factor towards ensuring safe and efficient operation of the range—including oven, broiler, griddle, and so on. Some of the major items that should be covered in inspections of oil- and gas-fired equipment are given below.

As part of the MONTHLY inspecton, check the piping for leaks, clean and lubricate motors, and check the burner flame. Remember that the burner should give off a blue flame if air-oil mixture is correct. A flue gas analysis should be performed to determine proper fuel-air mixture.

In addition, check the equipment for alignment and fit of doors, for sliding action of racks, and for levelness.

The ANNUAL inspection of oil- and gas-fired equipment should include a check on all parts for damage, corrosion, and lack of paint. Remove rust with solvents, and paint bare spots with heat-resistant aluminum paint. (Note: If bare spots total more than 20 percent of entire surface, paint the equipment.) The accuracy of thermostats should also be checked; if the thermostat cannot be adjusted to 5° F accuracy, replace it with a

Table 17-3.—Troubleshooting Chart for Ovens, Ranges, and Broilers

Trouble	Probable cause	Possible remedy
OIL-FIRED OVENS		
Motor will not start.	Blown fuse. Thermostat set below baking chamber temperature. Solenoid valve activated. Solenoid out of order.	Replace fuse. Set thermostat above oven temperature. Replace solenoid valve. Clean out foreign particles, look for evidence of wear.
Motor runs but oven fails to light.	Fuel tank empty. No ignition because of carbon formation. No ignition because of damaged transformer. Clogged fuel nozzle.	Fill tank. Clean carbon from electrodes. Replace transformer. Clean nozzle tip and screen. Also clean screens in fuel pump unit. If water and sludge are found in screens, fuel tank must be pumped out.
Combustion flame is disorganized and smoky.	Closed damper. Heavy soot deposits in flue pipes.	Open secondary air damper door. Remove flue pipes and clean.
Uneven cooking.	Secondary air damper door is too far open or too near shut.	Adjust secondary air door. Open wide for fast rates of firing, slightly for slow rates of firing.
Difficult ignition.	Oil supply is too low. Oil supply is shut off by solenoid valve.	Open oil regulating valve. Push reset valve on units having such equipment.
Burner starts and functions properly, but fails after short intervals.	Dirty burner openings. Air leaks in suction line. Clogged strainers. Oil tank vent obstructed. Controls out of order or improperly adjusted.	Clean parts of burner. Repair leaks. Clean strainers. Remove obstructions. Check controls. Adjust controls properly.
Burner puffs when started.	Poor or delayed ignition. Insufficient draft.	Clean the nozzle. Examine ignition assembly and test for short circuit. Adjust electrodes to proper position. Adjust damper. Examine flue passages and chimney for obstructions.

54.316.1

Table 17-3. — Troubleshooting Chart for Ovens, Ranges, and Broilers — continued

Trouble	Probable cause	Possible remedy
OIL-FIRED OVENS—Continued.		
Flame pulsates when burner runs.	Insufficient draft. Down draft in chimney or fluctuating draft.	Check and adjust damper. Move air diffuser forward or backward to change air turbulence at nozzle tip. Examine flue passages for obstructions.
Smoke in combustion chamber or smoke from chimney.	Improper or defective nozzle. Nozzle partially clogged. Insufficient air.	Replace nozzle. Clean nozzle. Increase air intake opening. Provide adequate air supply to burner space.
Carbon forms in combustion chamber.	Oil spray impinges on walls. Excessive oil burning rate.	Check nozzle to see if correct model. Clean nozzle, if necessary. Reduce oil pressure or install smaller size nozzle.
Fire is on one side.	Nozzle is damaged or dirty.	Clean or replace nozzle.
High oil consumption.	Too little air. Dirty heat absorbing surfaces. Excessive draft. Leak in oil storage tank.	Increase air intake. Clean ducts. Reduce draft by adjusting damper. Repair tank.
Solenoid valve fails to function.	Defective solenoid valve. Thermostat damaged. Defective connections. Emergency bypass valve open. Dirty solenoid valve.	Replace solenoid valve. Replace thermostat. Repair connections. Close emergency bypass valve. Disassemble valve and clean parts.
Pilot flame inoperative or too low.	Setscrew adjustment too tight on back of solenoid valve. Fuel passage clogged.	Adjust setscrew to increase fuel for pilot flame. Remove solenoid valve pilot flame setscrew and clean both stem and port.
Oven overheats.	Thermostat damaged. Solenoid valve plunger does not drop to shutoff position.	Replace thermostat. Tap body of the valve gently. Clean solenoid valve and replace.
Oven underheats.	Fuel line clogged. Fuel shutoff valve not full opened at tank. Vaporizing parts full of carbon.	Clean fuel line. Open the shutoff valve to the maximum. Remove all carbon.

54.316.2

Table 17-3. — Troubleshooting Chart for Ovens, Ranges, and Broilers — continued

Trouble	Probable cause	Possible remedy
GAS OVENS AND RANGES		
Fails to ignite.	Insufficient or no pilot flame. Main gas valve or shutoff valve adjacent to oven is off. Air shutter completely closed.	Light and/or adjust pilot flame. Turn on gas valve. Adjust air shutter.
Oven does not heat fast enough.	Gas input too low or not in proper adjustment. Cooling damper open.	Clean burner. Adjust burner controls. Close cooling damper.
Uneven cooking.	"Soft" flame. Too much draft pulling heat out through flue. Doors do not close tightly.	Adjust bypass flame. Remove excessive draft. Remove accumulation around door edges.
No gas.	Main service valve closed. Solenoid valve not opening.	Open main service valve. Clean solenoid valve.
Constant "burning."	Too much draft. Faulty thermostat.	Remove excessive draft. Replace thermostat.
Temperature rises when oven is not is use.	Low flame setting is too high.	Cut low flame to a minimum. Shut off burner when oven is not in use, leaving pilot on.
Fumes in room.	Faulty chimney, or back draft, or improper gas adjustment. Fan running in room with doors and windows closed causing vacuum.	Inspect and correct defective ventilation system. Open window or door to eliminate vacuum.
Flare back on turn-down.	Bypass flame too low.	Adjust bypass flame.

54.316.3

new thermostat. Clean off soot deposits, jet openings, and repair or replace leaking piping. Clean and tighten nuts and bolts.

See table 17-3 for a troubleshooting chart covering the maintenance of ranges, ovens, and broilers.

BAKERY OVENS

Most large naval galleys have a bakery department, which is usually physically separated from the main galley. Various types of bakery equipment are available, but detailed coverage on this equipment is not provided in this training manual. Brief coverage will be given, however, to bakery ovens, which is one of the most common types of bakery equipment.

Both sectional and cabinet types of oven are commonly used in bakeshops at Navy activities. Another common type is the reel (or revolving-tray) type of oven; a diagram of a typical reel oven is shown in figure 17-8. The reel oven has a h[illegible]zontal circular platform that revolves slowly; and, the loading and unloading are done

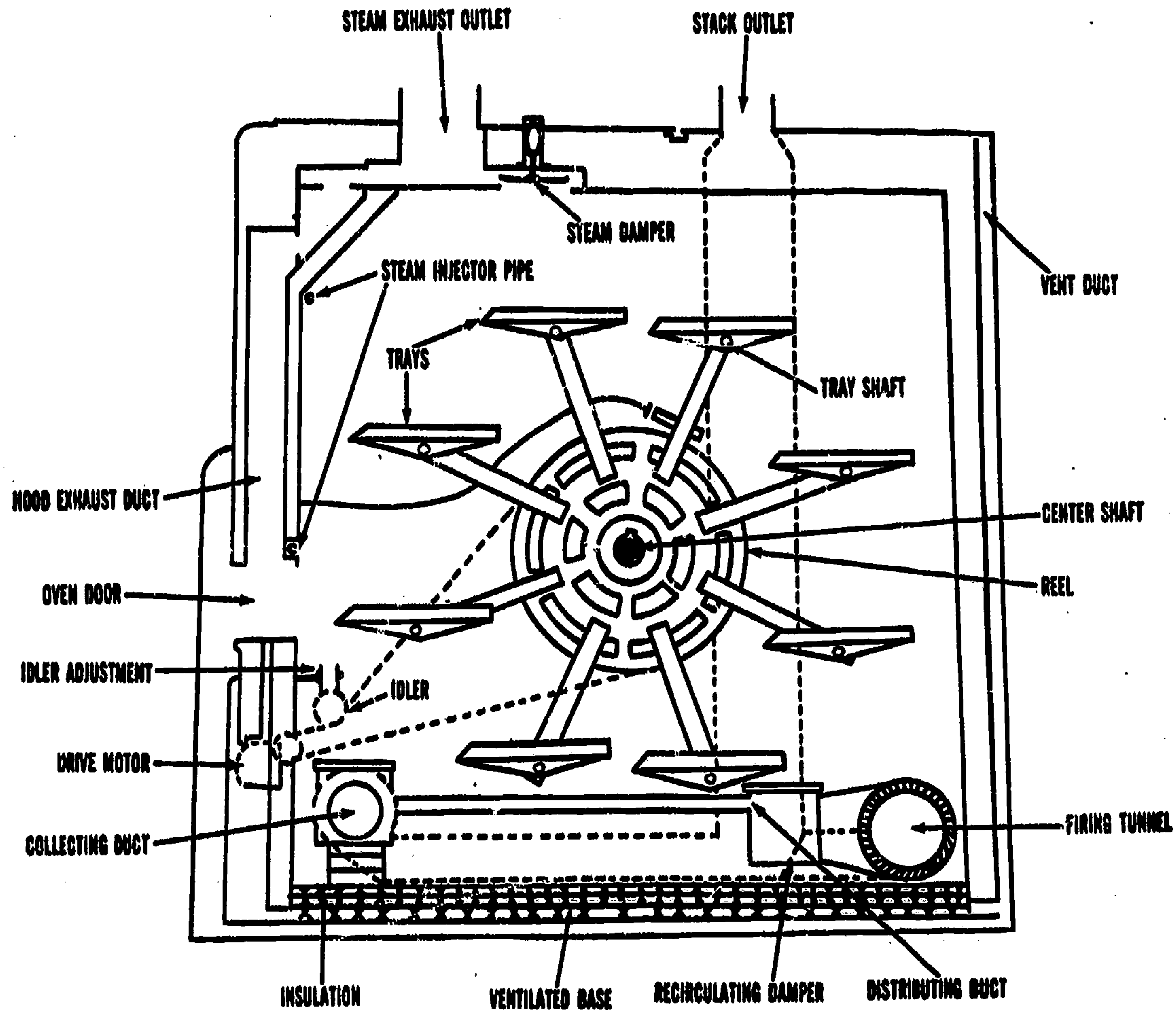


Figure 17-8.—Reel oven. 54.12

at the same door. Bake ovens may be gas-fired, oil-fired, or electrically heated.

Installation

The INSTALLATION of ovens may vary, depending upon the type of oven and the manufacturer. To ensure proper installation, the drawings and specifications that accompany the oven should be followed carefully. Only a few general details, which frequently will apply, are provided here.

Most large models of baking ovens are installed on a masonry hearth. Gas-fired equipment must be placed on masonry hearths if the bottom of the combustion chamber is less than 8 inches above the floor. Venting of baking ovens is basically the same as the requirements for ranges and ovens discussed previously. Temperature control is accomplished by thermostats of the same type used on range ovens.

Maintenance

Routine maintenance of bakery ovens requires weekly, monthly, and annual inspections.

WEEKLY inspections should include adjustments of heating units for proper fuel-air mixtures and constant operating temperature. Check the pilot flame of gas-fired ovens and adjust it, if necessary, so that the burner gas ignites without wasting fuel and the flame is not blown out by the flue draft; adjust the fuel-air mixture to produce a blue flame. Check operation of the purging fan and flame failure devices. Clean soot and dirt from the pilot and gas burner. Check the oil supply for leaks and stoppages and clean the strainer basket of oil-fired ovens. Try the operation of electric-ignition and flame failure devices, and repair if necessary. Adjust the oil burner for proper spread of fuel across the combustion chamber and for proper fuel-air mixture to maintain a blue flame. Examine the operation of dampers and clean and adjust if required. Check the settings of automatic temperature and humidity controls; and reset the settings of the thermostat and humidistat if necessary.

MONTHLY inspections should cover inspection of the conveyor and drive, and adjustment of loose chains, tensions, and misalignment. Adjust the chains of the V-belt tension by moving the idler sprocket or sliding motor base. Check the lubrication of gear boxes, bearings, and moving parts. Examine the oven top and walls for cracks and breaks; make repairs if necessary to ensure tightness.

When making an ANNUAL inspection of bakery ovens, drain, flush, and renew lubricant in the gear boxes. Check the lubricant of sprockets, gears, and bearings and renew in accordance with the manufacturer's instructions. Have electrical checks made of the insulation resistance of motor windings, controls and wiring. Clean all contacts of controls. Remember that all electrical work should be done by a qualified electrician.

INTERCEPTORS AND GREASE TRAPS

Removal of grease from greasy wastes is necessary if the sewage system is to function properly. One way grease is collected is by ceramic or cast-iron grease interceptors installed inside mess halls. Among types of interceptors you may encounter is the Zurn greaseptor illustrated in figure 17-9. Another method of collecting grease is by means of concrete or brick grease traps outside of buildings. Mess personnel will probably handle the cleaning of

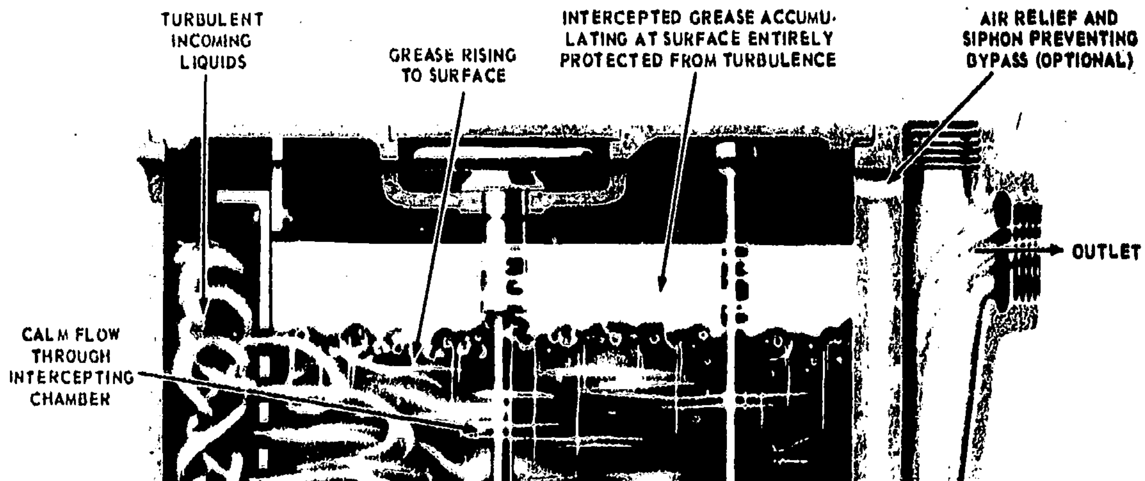


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Figure 17-9.—Zurn greaseptor.

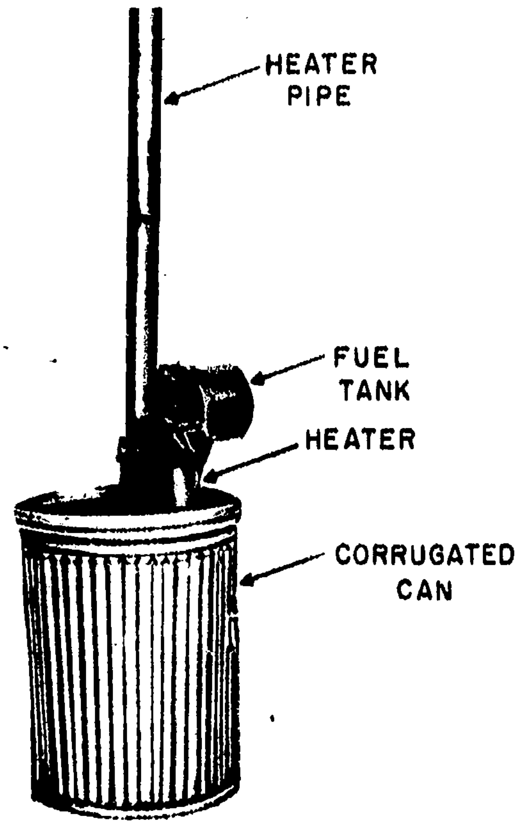


Figure 17-10.—Immersion heater installed in corrugated can. 48.75(54)

inside interceptors but you may have to take care of cleaning outside traps. If inside grease interceptors are maintained properly, they should collect most of the grease from greasy wastes; this may necessitate cleaning once each day.

Remember that outside grease traps are intended to serve kitchen plumbing fixtures and equipment only. For that reason, they should never be connected to soil and waste lines from toilet rooms. To help ensure proper functioning, clean grease traps at least once a week. Since accumulated odor forming solids cause septic action within a relatively short time, remove all solids each time traps are cleaned. The following procedure will provide a guide for cleaning outside grease traps.

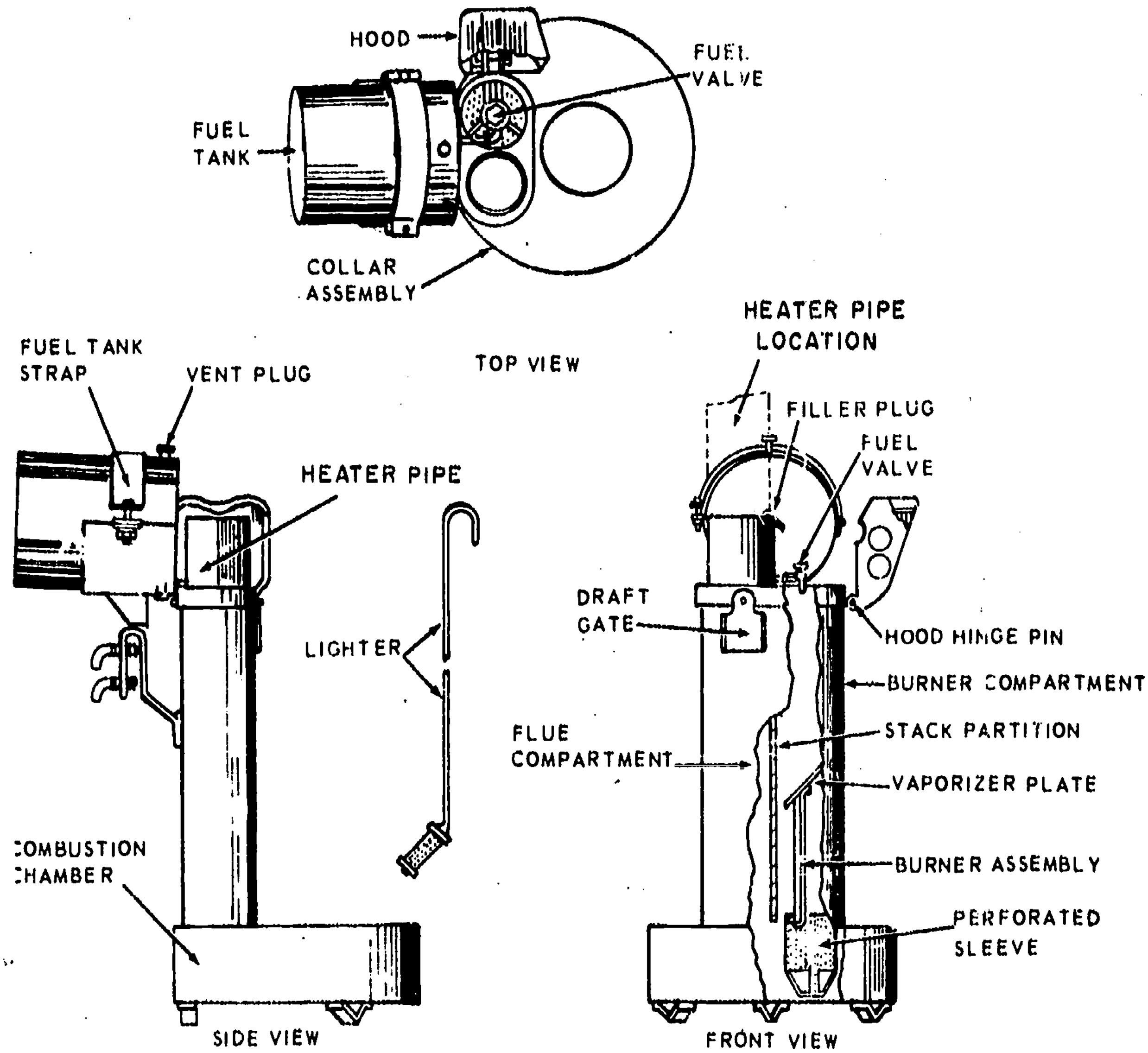
1. Using an ordinary perforated sewer scoop, skim grease from the surface of the trap and place in suitable containers for disposal.
2. Remove as much odor forming material as possible with the same scoop. Treat this refuse as disposable refuse.
3. If necessary, pump out liquid contents from traps every 3 months and remove all sediment from side walls and bottom.

IMMERSION CAN HEATERS

Immersion, liquid-fuel-fired heaters can be used in corrugated cans and in tank trailers. The main purpose of these heaters is to supply a field unit with hot water that is safe and economical. As a Utilitiesman, you will be concerned with the type of immersion heater used in corrugated cans, so it is with this type that we are concerned here.

One model of immersion heater that can be installed in corrugated cans, and which you may encounter in your work, is model FSN 4540-266-6835; the instructions in this discussion on immersion heaters apply to this model. An immersion heater installed in a corrugated can is shown in figure 17-10. The location of various major parts of the immersion can heater FSN 4540-266-6835 are shown in figure 17-11.

The body of the corrugated can heater is of watertight, sheet-steel construction and consists of a doughnut-shaped combustion chamber and a stack assembly welded together. A vertical partition divides the stack into two compartments: (1) the burner compartment which houses the burner, and (2) the flue compartment through which combustion gases leave the heater. The partition between the two stack compartments



54.11

Figure 17-11. —Major parts of the immersion can heater.

extends to the bottom of the heater and causes air entering the chamber from the burner compartment to circulate completely around the chamber before leaving by way of the flue compartment. A swing-type draft gate is located on the side of the flue compartment, near the top. The hanger is a length of bar-steel welded to the body of the heater. It is bent to fit the rim of the can and is provided with two clamping hook bolts to ensure mounting on the can. An instruction plate is located on the hinged hood (fig. 17-11) which covers the top of the burner compartment. The vaporizer plate of the down-draft burner consists of a 3/32-inch layer of absorbent asbestos, sandwiched between two perforated ovals of corrosion-resistant steel. The fuel tank is held in place by a cradle and strap assembly. The fuel tank is equipped with a valve assembly, a vent plug, and a filler plug, all located on the same end of the cylindrical tank. The heater is equippped with an 8-foot heater pipe that consists of four sections of pipe. The perforated cylinder on the end of the lighter is filled with absorbent asbestos. The immersion heater utilizes leaded or white gas as its normal fuel.

Additional information on the immersion heater is given below.

CAPACITIES

Fuel tank	2.2 gallons

Heat output	35,000 British Thermal units
Cubage, crated	5.6 cu. ft
DIAMETER	
Combustion chamber	15 inches
Pipe	4 inches
Length	
Burner	12 3/8 inches
Heater only	30 inches
Heater with fuel tank	33 3/4 inches
Heater with pipe section	9 ft 8 inches
WEIGHT	
Complete	44 pounds
Crated	60 pounds

DIFFERENCE IN MODELS

Basically, all immersion heater models are essentially the same in construction and for application. However, a primary difference lies in the method in which each heater is preheated and ignited. For example, to light the immersion heater FSN 4540-266-6835, a lighter torch must be manually inserted first in the flue compartment, and then into the burner compartment. Model 447-2EX immersion heater has a lighter cup which is mechanically pivoted inside the burner compartment. The lighter cup pivot forms a handle and extends outside the burner compartment. The operator need only to move the handle to pass the lighter cup from flue compartment to burner compartment.

INSTALLATION

Before you install an immersion heater, be sure you check the entire heater assembly for signs of physical damage. See that the heater is properly assembled, secure, clean, correctly adjusted and shows no evidence of fuel leaks. Select a site that is level and as sheltered as possible.

Install the fuel tank in the cradle and strap assembly and secure it with the wingnuts provided. DO NOT attempt to install a heater with a full tank of fuel because this will unbalance the heater and cause it to fall. Place the burner in the burner compartment, with the vaporizer plate end facing up. Now attach the four 2-foot sections of heater pipe (stove pipe) to the collar on the heater. Attach the heater to the can and tighten the locking screws or thumbscrews. Fill the can with water to within 6 inches below the collar assembly of th heater. If necessary, snow may be put into the can and be melted into water. Correct deficiencies, if any, before placing the heater in service.

OPERATION

When putting the immersion heater into operation, it is important that the flue be preheated. The following procedure will provide a guide for preheating the flue of the immersion heater FSN 4540-266-6835:

1. Open the vent plug as far as possible.
2. Soak the lighter in a mixture of half gasoline and half engine oil. DO NOT saturate the lighter by holding it under the fuel drip valve.
3. Use a match to ignite the lighter.
4. Swing the draft to one side and insert burning lighter into the flue compartment. The heat from the lighter causes a draft down the burner compartment, around the combustion chamber, and up and out the flue compartment.
5. Remove the lighter in about 2 minutes and close the draft gate.

Immediately after preheating the flue, place the burning lighter on top of the vaporizer plate. As a safety measure when doing this, make sure you wear gloves. Then open fuel valve slightly and allow fuel to drip on vaporizer plate. Adjust fuel valve until flows in rapid drops but not in a fine stream. Leave the lighter in the burner compartment until its flame burns out; then remove the lighter. Make final adjustment of fuel to obtain a desired flame. Then close the hood and leave it closed during operation. And finally, check for and wipe up any spilled fuel.

CAUTION: DO NOT EXPOSE YOUR FACE TO THE BURNER CHAMBER WHILE LIGHTING.

If you want to stop an immersion heater, first close the fuel and vent valves. Then remove the stack and fuel tank from the heater assembly. Remove the heater from the can and turn it upside down so that any accumulated fuel in the combustion chamber can drain out.

Pointers on operating immersion heaters under unusual conditions are explained below.

During extremely cold weather, operate the heater under a shelter if possible. Be sure to pipe exhaust fumes outside. If the heater must be operated outside, provide a windbreak such as a tent, building, truck, or tarpaulins. Leave burning lighter in the flue compartment for about 4 or 5 minutes, instead of the usual 2 minutes when preheating the flue.

When operating in extremely hot weather, exercise great care in lighting and operating heaters, because of rapid evaporation of the fuel under these conditions. Under tropical conditions, remove condensation from heaters with dry cloths to keep the equipment as free as possible of moisture.

When operating in heavily rainfall areas, upend the heater before each operation to drain any water from the combustion chamber. Protect the heater with an overhead shelter whenever possible. Remember, DO NOT expose the burner to moisture. The asbestos layer in the burner will absorb water and this will interfere with operation of the heater.

PREVENTIVE MAINTENANCE

To ensure that the immersion can heater is ready for operation at all times it must be inspected systematically so that defects may be discovered and corrected before they result in serious damage or failure. Various preventive maintenance checks and services to be performed are listed in table 17-4. Additional pointers on the care of the immersion heater are given below.

Wipe dust and grease off the heater body, using a clean cloth. If rust spots are present, remove with a fine grade of sandpaper. Check the heater body for dents and open seams. Beat out dents and have welds repaired as necessary. Repaint the exterior surfaces of the heater, if needed. DO NOT paint the heater below the waterline. Furthermore, DO NOT paint the interior surfaces or any part of the heater pipe.

Clean the vaporizer plate of the burner and perforated sleeve with a stiff-bristled brush. Remove carbon, grit or other foreign matter from holes in the burner. Check the burner for corrosion and for damages such as distortion, cracks, or breaks; if the burner is unserviceable, replace it.

Remove heater pipes and clean soot from pipe sections. Wash the exterior of pipe sections with a brush and hot water. Dry pipe sections thoroughly. Check pipe sections for holes, dents, and excessive rusting. Replace pipe section as required.

Check the vent plug gasket for evidence of deterioration. Remember, DO NOT remove the vent plug from tank.

TROUBLESHOOTING

Some of the malfunctions which may occur in the immersion heater are listed in table 17-5. Each

Table 17-4. — Preventive Maintenance Checks and Services — Immersion Can Heaters

ITEM NUMBER	INTERVAL						B-BEFORE OPERATION A-AFTER OPERATION M-MONTHLY D-DURING OPERATION W-WEEKLY Q-QUARTERLY	
	OPERATOR				ORG.			
	DAILY							
	B	D	A	W	M	Q	ITEM TO BE INSPECTED	PROCEDURE
1	X		X				Fuel tank	Be sure fuel tank is filled with correct fuel.
2	X	X					Heater assembly	Inspect for proper installation.
3	X	X					Installation	Be sure fumes are piped outside if heater is to be operated in a building or tent.
4	X						Combustion chamber	Inspect for broken welds and holes. Check combustion chamber to be sure there is no unburned fuel in it.
5	X						Fuel	Inspect for leaks or spilled fuel.
6	X						Water level	Check water level
7	X	X					Vent plug	Inspect control
8		X					Fuel valve	Adjust fuel flow
9			X	X	X		Heat body	Inspect for clean condition.
10				X	X		Burner	Inspect and service.

54.414

Table 17-5. — Troubleshooting the Immersion Heater

MALFUNCTION	PROBABLE CAUSE	CORRECTIVE ACTION
1. Heater fails to start	*a.* Insufficient preheating of flue.	*a.* Repeat preheating. Leave lighter in flue compartment until heater starts.
	b. Vent plug closed.	*b.* Open vent plug.
	c. Fuel tank empty.	*c.* Remove and fill tank.
	d. Water present in combustion chamber.	*d.* Stop operation and clear water from combustion chamber.
2. Burner goes out	*a.* Fuel tank empty.	*a.* Remove and fill tank.
	b. Vent plug closed or clogged.	*b.* Open vent plug and be sure it is free of obstruction.
	c. Water present in combustion chamber.	*c.* Stop operation and clear water from combustion chamber.
	d. Fuel rate too slow.	*d.* Open fuel valve.
	e. Flame blown out.	*e.* Shield heater from wind.
3. Heater smokes	*a.* Fuel rate too fast	*a.* Close fuel valve slightly.
	b. Stack is too short	*b.* Be sure to use at least four sections of pipe.

54.415

malfunction stated is followed by a list of probable causes of trouble. The corrective action recommended is described opposite the probable cause.

SAFETY PRECAUTIONS

This section contains safety information for operators and users of immersion heaters.

1. Do not fill fuel tanks indoors—spillage may cause a hazardous condition.

2. Wipe up all spilled fuel and be sure that the fuel valve end of the tank is free of fuel and dry.

3. Ensure that the heater installation is complete and meets installation requirements.

4. Do not operate the heater in a totally confined area. Sufficient ventilation to eliminate the accumulation of carbon monoxide fumes must be available.

5. Inspect the fuel container and lines for leaks. Repair leaks before lighting the heater.

6. Keep fuel outside the tent. Never store spare cans of fuel in the tent.

7. A fire extinguisher should be readily available for use, and all personnel instructed in the use of such fire extinguisher.

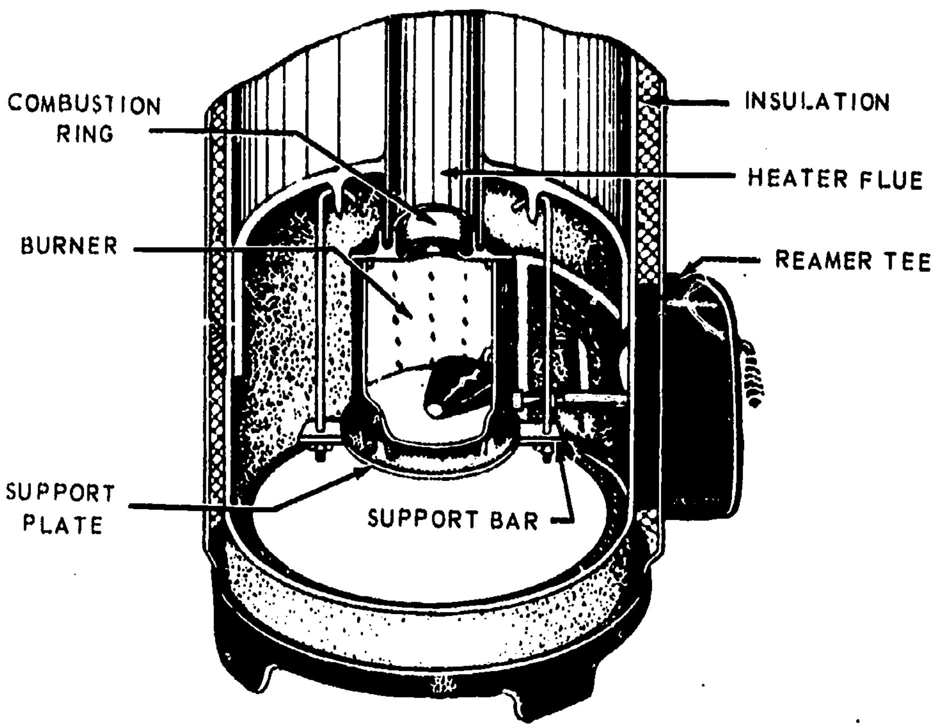
8. Do not pour gasoline or oil on fire during operation.

9. Do not operate the stove at full blast even in extremely cold weather. An overheated heater pipe may ignite tentage.

OIL-FIRED SPACE HEATERS

In areas where oil is the principal fuel, oil-fired space heaters are used for many space heating requirements. Oil-fired space heaters are very simple in construction. They consist of a burner, a combustion chamber, an outer casing, a fuel tank and fuel control valve. An air space is provided between the combustion chamber and the outer casing. Air enters through grilles in the bottom of the heater, is heated and passes out through grilles in the top of the unit. Some oil burning heaters are equipped with a blower and electric motor to force the heated air out into the room. They turn at a slow speed and may be either direct drive or belt driven.

Oil-fired space heaters have atmospheric vaporizing type burners, two types of which are described briefly below. The burners require a light grade of fuel oil which will vaporize readily at low temperatures and leave only small amounts of carbon and ash. Number 1



54.190

Figure 17-12. —Cutaway view of a natural draft pot-type burner.

fuel oil is generally used. The two types of oil-fired space heaters that we will be discussing are the natural draft pot and perforated sleeve type.

NATURAL DRAFT POT DISTILLATE BURNERS are widely used for space heaters, room heaters, water heaters, and so on. A cutaway view of a natural draft pot-type burner is shown in figure 17-12. In operation, the distillate (oil) is fed at the bottom of the burner; either at the center or on the sides, and is vaporized at this point by radiant heat from above. The vapors rise and mix with the air drawn through the perforated holes in the burner. During high fire conditions, the flame burns above the top combustion ring, as in figure 17-13, and under low fire conditions, the flame burns in the lower portion or pilot ring of the burner as in figure 17-14.

The PERFORATED SLEEVE BURNER consists of a metal base formed of two or more circular fuel vaporizing grooves and alternate air channels (see fig. 17-15). Several pairs of perforated sleeves or cylinders, one inside the other, are mounted on the base. Each pair of perforated sleeves forms a combustion chamber above its own grooves. One or more cover plates resting on top of the nested cylinders baffle the flame and close the air passage, thus forcing air through the perforations into the oil vapor chamber. In this way a large number of jets of air are introduced into the oil vapor, bringing about a good mixture. This mixture burns with a blue flame and is clean and odorless.

For ease in lighting, these burners usually have a short asbestos kindling wick. Some burners have a cup below the base in which alcohol is burned to provide heat for starting. The wick and alcohol are used only for lighting.

INSTALLATION

Oil burning heaters are portable and are easily moved from one location to another. For satisfactory operation, follow the installation procedures supplied by the manufacturer. In both perforated sleeve and pot type burners, oil is fed to the burner under control of a float-operated metering valve (see fig. 17-16).. Set the unit level so the oil can be properly distributed in the burner.

A point to remember is that: THE FUEL LEVEL CONTROL VALVE IS THE ONLY SAFETY DEVICE ON THE OIL-FIRED SPACE HEATER.

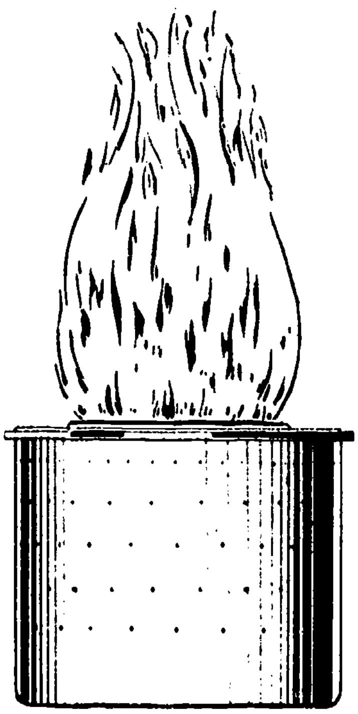


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Figure 17-13.—High fire flame.

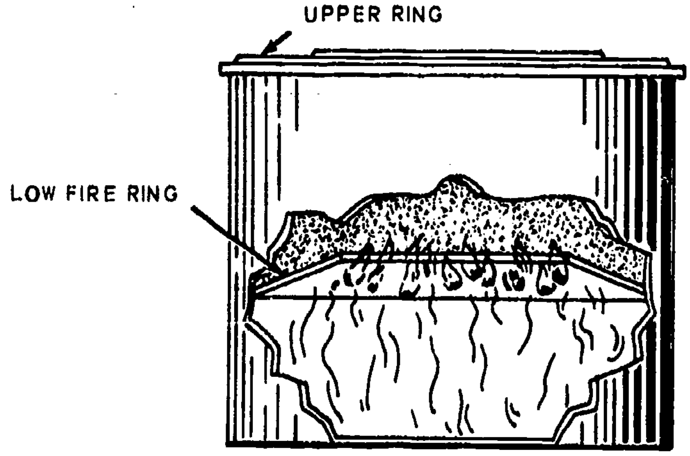

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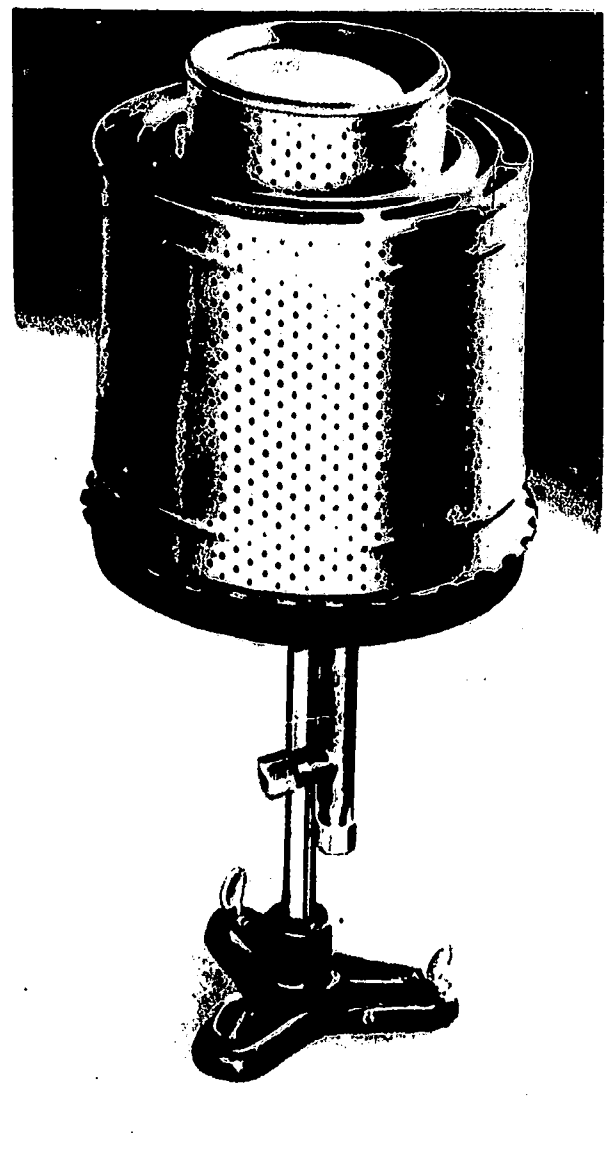
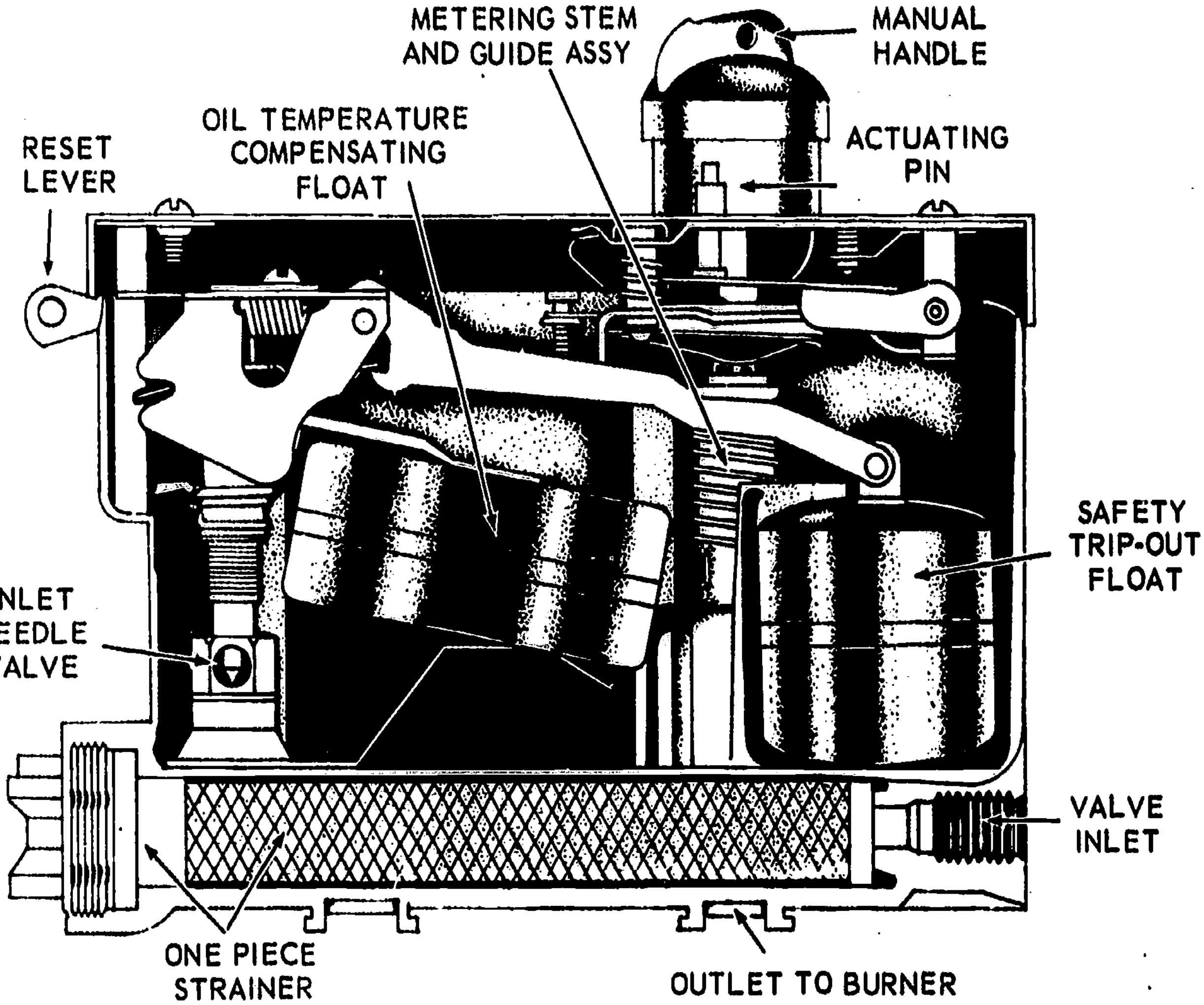
Figure 17-14.—Low fire flame.

When several space heaters are installed in a building, an oil supply from an OUTSIDE TANK to all heaters is often desirable. This eliminates frequent filling of individual tanks and reduces waste from spilling. Figure 17-17 shows the principal elements of such a system and important points to consider during installation.



54.13
Figure 17-15.—Perforated-sleeve burner.

See that the space heater is placed a safe distance from the wall. You will also need a metal pan made of sheet metal for it to sit in. This will catch the oil if a leak occurs; do not use a sand box or cement as both absorb oil and create a fire hazard. In the case of wood floors, place a piece of asbestos on the floor underneath the metal pan. Asbestos may also be needed on the wall behind the heater if the wall is made of wood.



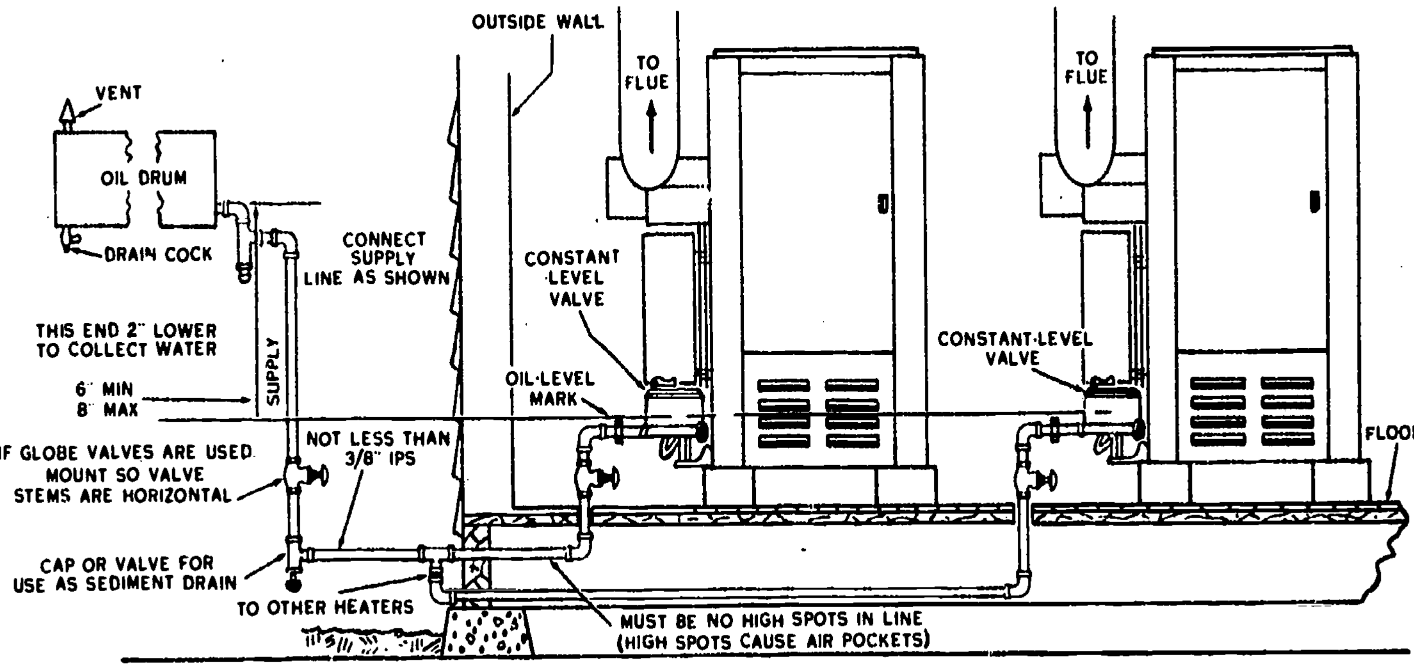
54.16(54)

Figure 17-16.—Oil control metering valve.

Since the flow of air to vaporizing type burners is induced by the chimney DRAFT, pay careful attention to this feature. The draft produced by any chimney depends upon the height of the chimney and the difference in temperature between the flue gas and outside air. The cross-sectional area required depends upon the volume of flue gas to be carried. Since outside air temperature varies during the heating season, arrange the chimney or flue to produce necessary draft under the most unfavorable conditions likely to be encountered, usually an outside temperature of 60° F. Above this temperature heat is not usually required, and below this temperature draft would be increased.

Install the draft REGULATOR to maintain a constant draft adjustment for the rate at which the heater is fired. The regulator is a swinging damper or gate with provision for adjustment. Since balance and free action are the fundamentals on which its operation depends, be sure the installation provides for these features. Install the damper section with the word TOP at true top position. Make sure the face is plumb. When the damper regulator is installed in a horizontal or nearly horizontal run of pipe, do not use a counterweight on the damper.

DOWN-DRAFT may seriously interfere with proper functioning of these burners. Down-draft may result when the chimney is not high enough above the roof line or is too close to other high buildings, trees, or terrain features. The chimney top must be at least 3 feet above the highest point of the building roof. If the difficulty is caused by other factors, a down-draft hood may prove effective. There are



54.193

Figure 17-17.—Space heaters installed in series.

several successful designs; a simple constructed type is shown in figure 17-18.

Copper tubing is often used in an oil supply system because of its high resistance to corrosion and ease of installation. It comes in rolls of 50 to 100 feet from which the needed length is cut. Tubing sizes are listed by the outside diameter and wall thickness, instead of by the inside diameter as in the case of iron pipe.

Tubing may be cut easily with either a tubing cutter or a hacksaw. The cut ends must be reamed to remove any burrs or roughness that might restrict the flow of fuel or hamper the installation of fittings. A major advantage in using copper tubing is that it can be bent easily without collapsing the tube, especially if a tubing bender is used; this cuts down on the number of fittings required.

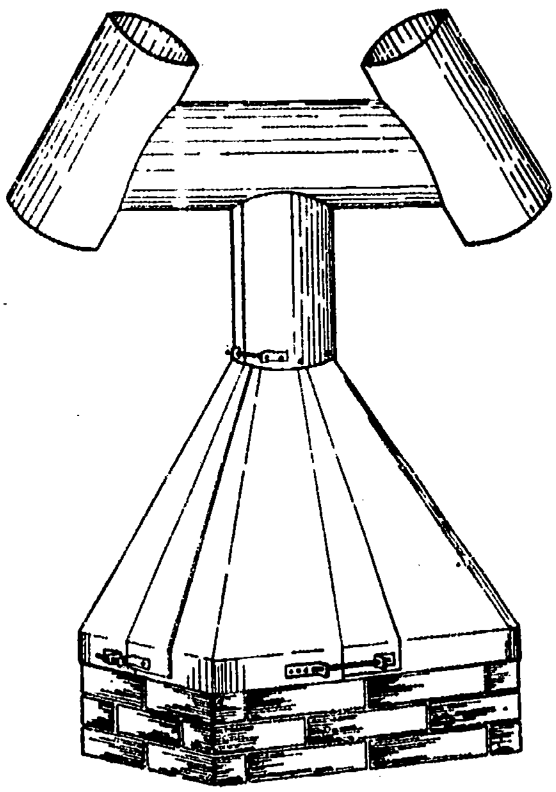
MAINTENANCE AND CARE

Oil enters the burner at the center or side of the bottom of the bowl and is vaporized close to the point of entry by radiated heat from above. The vapors rise and mix with air drawn in through holes in the sides of the bowl. The fire is usually controlled manually. With high fire the flame burns from the flame ring at the top of the pot, and with low fire it burns from the pilot ring down in the pot. Do not let the flame burn on the bottom of the pot.

The position of the flame depends upon the quality of vapor produced. These units burn oil vapor, not liquid oil. The quantity of vapor produced depends upon the oil level in the pot and heat available to vaporize it. After vapor forms it must be mixed with enough air to burn.

To CLEAN SOOT from heaters, take the casing and flue pipe off and remove from the heater. Some heating elements may be cleaned by simply tapping the element with a piece of wood to loosen the soot, which may then be removed by running a flexible hose from a vacuum cleaner through the unit. If air pressure is to be used to blow out soot, first move the heater out of the building.

The OIL-CONTROL METERING VALVE used for these burners (see fig. 17-16) maintains a given level of oil in the burner to operate the heater at the rate desired. The rate is a minimum at START position of the control knob and increases progressively to maximum at HIGH position. Adjusting screws are provided for making further adjustment for either LOW or HIGH position, if necessary. Access to these screws is obtained by removing the cover plate. Initial adjustment rarely requires changing, unless the grade of oil is changed. The safety float provides a safety cut-off for oil flow when



54.15
Figure 17-18.—H-type down-draft hood.

the level rises above the safe limit point. If it does so rise, after the valve is tripped by the float, determine and correct the fault, then reset the unit with the lever provided. The strainer may be removed for cleaning by unscrewing the strainer nut.

FIRE PROTECTION

While deployed outside the continental United States in a battalion, fire prevention and firefighting equipment are matters of chief concern to SEABEE personnel. SEABEES will normally have their own camp area, consisting of tents, quonset huts, or other types of buildings—as required for living and working areas. Persons occupying or working in these structures should have a good background knowledge of fire prevention and fire protection.

Firefighting equipment and procedures described in Basic Military Requirements, NavPers 10054-C and Military Requrements, for Petty Officer 3 and 2, NavPers 10056-C provide a lot of useful information. Although most of the equipment is slanted for shipboard-type firefighting, the classes of fire will remain the same.

Procedures for reporting fires, as well as types of firefighting equipment available, may vary from one activity to another. For that reason, only general information will be presented here. When assigned to a new activity, you would be wise to acquaint yourself, as soon as possible, with the procedure for reporting fires and the types and location of firefighting equipment available. See that you also know the techniques to use in operating the equipment and the principles behind its operation.

It is a good idea that you have a knowledge of first aid. Among other things, know how to treat burns, how to give artificial respiration, and how to stop bleeding. An excellent reference on first aid is the Standard First Aid Training Course, NavPers 10081-B. Remember that sometimes you cannot wait for medical aid.

WHAT IS FIRE?

Combustion, or fire, may be defined as oxidation taking place at a rate rapid enough to produce light and heat. Combustible materials heated to their ignition temperature unite with the oxygen of the surrounding atmosphere and burn. Ignition temperature, an adequate supply of oxygen, and the presence of fuel are all necessary to the support of combustion. Fire is suppressed by decreasing the temperature below the ignition temperature, shutting off the supply of oxygen, removing the fuel, or by a combination of these means. Fire extinguishers are used to cool the burning material and curtail the oxygen supply.

CLASSIFICATION OF FIRES

Accepted standard practice separates fires into four general clases: class A class B, class C, and class D.

CLASS A fires involve wood, paper, cloth, rubbish, and explosives. These fires are fought with water.

CLASS B fires involve substances like oil, gasoline, kerosene, and paint. These fires usually are fought with foam or fog.

CLASS C fires are those involving electrical and electronic equipment. Generally, carbon dioxide (CO_2) gas is used in fighting these fires.

CLASS D fires are those which involve certain combustible metals, such as magnesium, potassium, powdered aluminum, zinc, sodium, etc. Dry-powder extinguishers are used on all Class D fires.

FIREFIGHTING EQUIPMENT

Various types of firefighting equipment are used by the Navy. Three types which are commonly used at shore activities are the carbon dioxide (CO_2) extinguisher, foam-type extinguisher, and Purple-K-Powder dry chemical extinguisher. Each of these types is discussed separately in subsections below.

Carbon Dioxide Extinguisher

The portable 15-pound, carbon dioxide (CO_2) extinguisher shown in view A, figure 17-19 is very effective for putting out electrical fires and burning fuel or grease in confined spaces. The Navy standard CO_2 type extinguisher has a release valve like that illustrated in view B, figure 17-19.

To operate the portable 15-pound, CO_2 extinguisher, proceed as follows:

1. Carry the entinguisher in an upright position and approach the fire as closely as possible.
2. Remove the locking pin from the valve.
3. Grasp the horn handle. This handle is insulated to protect you against frostbite from the suddenly expanding CO_2 . Squeeze the release lever to open the valve and release CO_2 . Direct the flow of CO_2 toward the base of the fire. The maximum effective range of a 15-pound, CO_2 extinguisher is 5 feet from the outer end of the horn. This distance is reduced if the wind is against you and increased if the wind is with you. If possible, attack the fire from the windward side in order to increase the range and also to protect yourself from the heat of the fire. When the CO_2 is released, it forms "snow;" DO NOT touch this snow; it will blister your skin and may cause painful burns. Move the horn slowly from side to side and advance on the flames as they recede.
4. When conditions permit, close the valve. Continue to open and close the valve as the situation requires. When continuous operation is necessary, or when the valve is to remain open for recharging, slip the D-yoke ring on the carrying handle over the operating handle. The operating handle should be in the depressed position when you put on the D-yoke ring. The D-yoke permits continuous operation of the ex-

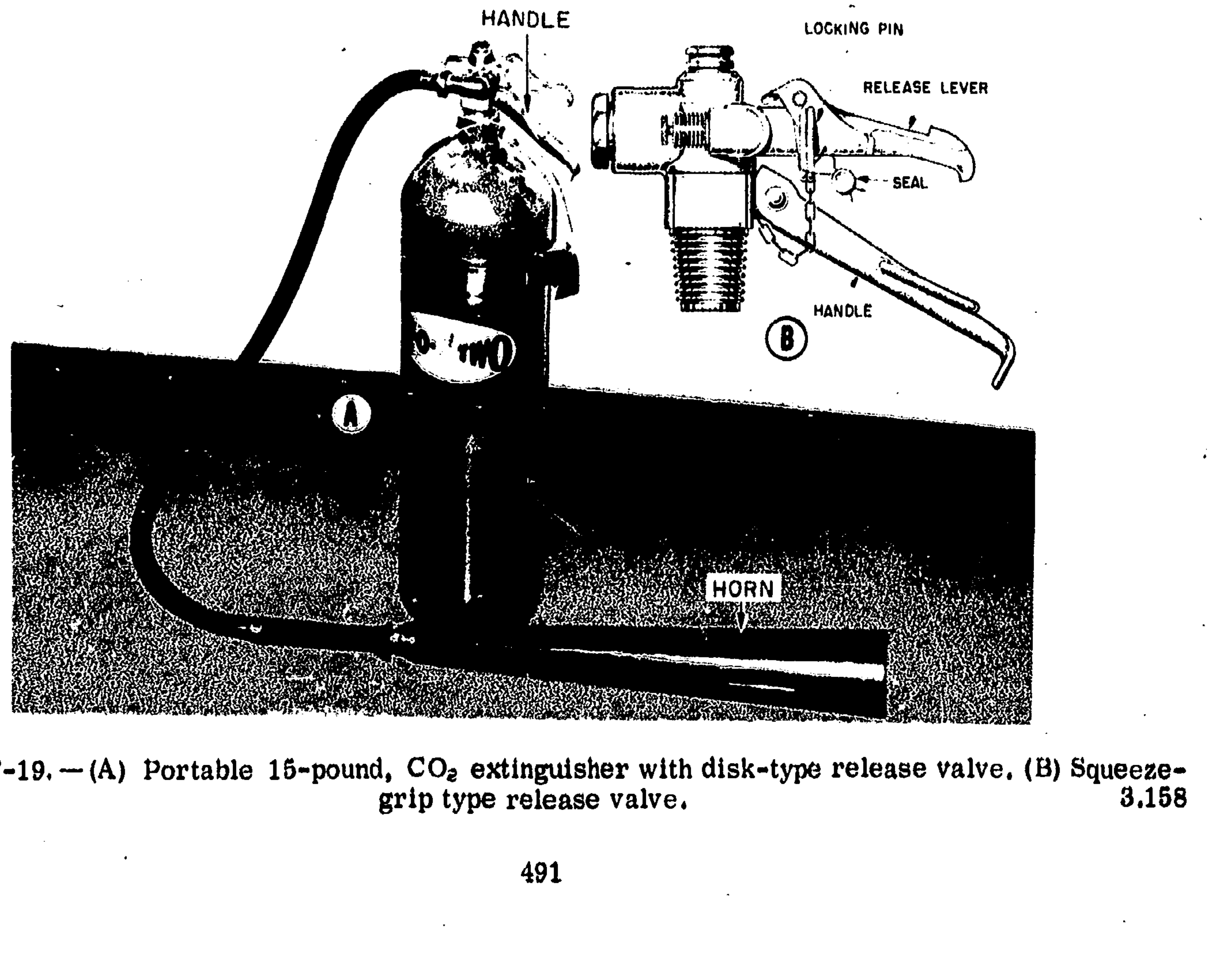


Figure 17-19.—(A) Portable 15-pound, CO_2 extinguisher with disk-type release valve. (B) Squeeze-grip type release valve. 3.158

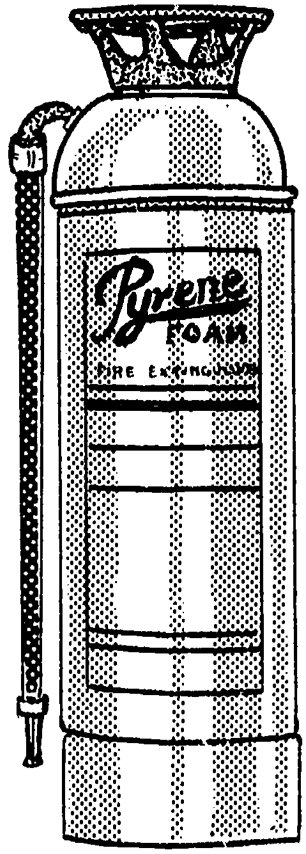


Figure 17-20.—Foam-type extinguisher. 81.40

tinguisher, as long as any CO_2 remains. Once a 15-pound cylinder has been used, it should be recharged before it is returned to stowage. The process of recharging CO_2 cylinders should be accomplished in a well ventilated space and should be done under the supervision of an experienced petty officer.

CO_2 is most effective in closed areas. If there is a wind or draft, work upwind to prevent the CO_2 from being blown away before reaching the flames. But remember, this gas is dangerous. Since it smothers and puts out fires by displacing or diluting oxygen in the air, the lack of oxygen could suffocate any person in the area. Therefore, no one should normally be allowed in a space where CO_2 has been released until the space has been aired for at least 10 minutes. If it is necessary to enter the space, wear Navy-approved rescue breathing equipment.

A CO_2 extinguisher must be inspected monthly. The date of each inspection and the initials of the inspector are noted on the "Inspection Record (Fire Extinguisher)." NAVDOCKS 2072 form, attached to the extinguisher.

Foam-Type Extinguisher

The foam-type extinguisher (fig. 17-20) has water in addition to several chemicals. When the extinguisher is not in operation, the water and the chemicals are separated from each other within the container. When you turn the container upside down to operate the extinguisher, the water and the chemicals mix to form a foam-like substance that smothers the fire on which it is sprayed. This extinguisher is especially useful for blanketing "liquid" fires on floors and machines. It is not recommended for electrical fires because of the danger of fouling the electrical system and causing shock.

Be careful not to upset foam-type extinguishers. Once upset or inverted, they will discharge all of their contents, leaving a sticky mess to be cleaned up.

Like the CO_2 extinguisher, the foam-type should be inspected monthly. Corrosion around

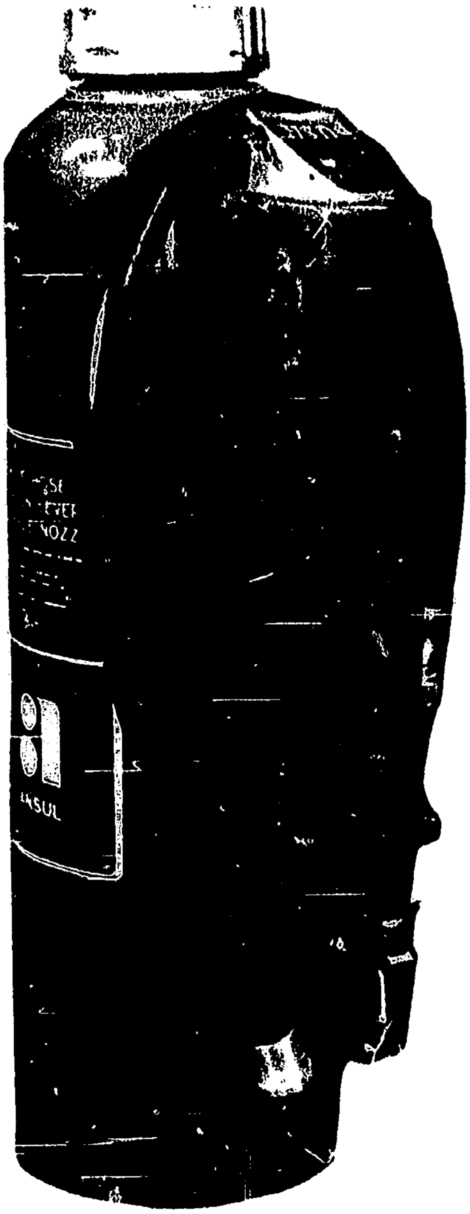


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Figure 17-21.—PKP fire extinguisher.

the nozzle indicates that the contents of the extinguisher have lost their strength and that the extinguisher needs recharging. Normally, foam extinguishers of the 1 1/4- and 2 1/2-gallon capacity should be discharged and recharged once a year.

PKP Dry Chemical Extinguisher

The dry chemical extinguisher which uses Purple-K-Powder (PKP) as a firefighting agent may be used against Class B and Class C fires. (See fig. 17-21.) PKP consists entirely of crystals of potassium bicarbonate, which is a non-toxic material closely related to the old baking soda extinguishing agent (sodium bicarbonate) but fully twice as powerful in fire killing ability per pound. Like carbon dioxide, however, it is a temporary extinguishing or smothering agent. Fires in fuels, like gasoline or hot diesel oil, can be quickly extinguished with PKP agent but unless ALL the fire and nearby sources of ignition are fully extinguished, the flame can flash back, and the fire will quickly return to its original intensity. For this reason, it is always advisable to back up dry chemical (or carbon dioxide) on hot Class B fuels with a permanent extinguishing agent such as foam.

PKP does not, as many people assume, smother a fire by cutting off the available supply of oxygen. PKP breaks the chain reaction which combines the heat, fuel and oxygen, thereby extinguishing the fire.

PKP is generally not harmful if inhaled. However, in confined spaces where large amounts could be inhaled, it can cause irritation to the breathing passages and induce coughing. It is therefore recommended that in confined spaces a breathing apparatus such as an oxygen-breathing apparatus (OBA), airline mask or Mk-5 gas mask be worn. PKP is considerably more effective than CO_2. However, some forethought should be given to using PKP on most Class C fires, because the residue from PKP is difficult to remove from electrical and electronic equipment. Besides potassium bicarbonate (PKP), the PKP fire extinguisher can also be used with other chemical agents such as CO_2 and nitrogen. These chemical agents come in cartridges. The Navy has selected CO_2 cartridges as standard cartridges for use in PKP entinguishers.

The PKP fire extinguisher is equipped with a locking pin and a lock wire. The locking pin assembly prevents inadvertent discharge of the CO_2 cartridge into the extinguisher shell which will cause eventual bleedoff of the cartridge pressure. Without the pin a sharp blow to the operating plunger (even with the hose in place) can cause the cartridge to discharge. The locking pin secures the plunger and prevents its being depressed. The lead seal (FSN 9Z-5340-292-0893), which should be single strand wire with a lead seal, serves as an indicator. This lock wire should be soft enough to be broken by hand. The extinguisher should be stowed with the lock wire in place to indicate that it is ready for use. The readiness of any extinguisher found without a lock wire installed should be suspect.

The Navy is constantly developing new methods of putting out fires; therefore, do not be surprised to find in your activity new types of equipment not discussed here. Now is the time to locate the extinguishers in your area and to make certain that you know how to use them. And remember to respect the sign FOR FIRE ONLY; it may save your life.

You should also know the location of the nearest fire alarm box and how to get in touch with the fire crew. The fire crew will have to handle fires too big for portable extinguishers; the fire crew must also be called when no extinguisher is available. All fires must be reported to the Fire Marshal.

Ensure that PKP extinguishers receive weekly, quarterly and routine inspections as called for on Maintenance Requirement Cards.

CHAPTER 18

LAUNDRY EQUIPMENT

Laundry equipment may vary from one activity to another, depending upon such factors as the size of laundry and differences in individual types of equipment produced by various manufacturers. Among common types of equipment used in most laundries are washers, extractors, and drying tumblers.

One type of laundry unit which you may encounter in your work is illustrated in views A, B, and C of figure 18-1. This laundry unit is mounted on three skids, which are fitted together in assembling the unit. View A shows a washer unit which consists of two 75 pound 26" x 26" end-loading washers, and one 30" top-loading extractor. View B shows the dryer unit, which consists of two 42" x 42" steam-heated drying tumblers, one air compressor, electric motor-driven; and one stainless steel surge tank. The boiler unit, shown in view C, consists of an oil-fired 33-hp steam generator, with a return hot well, a water softener, and a 350-gallon hot water storage tank. This laundry unit has a capacity for washing and fluff drying 225 (dry weight) pounds of laundry per hour.

In the following sections, instructions are given in the installation, maintenance, and minor repair of a laundry washer, extractor, drying tumbler, and steam generator. The instructions are not intended to tell you all you need to know about the installation, maintenance, and repair of laundry equipment. For detailed information, refer to the instruction manual provided by the manufacturer of the equipment concerned.

WASHER

The purpose of the washer is to wash clothes and other suitable materials. The washing process is a series of baths during which soil is loosened from the materials, suspended in the water, and finally rinsed away. Several baths are usually necessary to effect complete soil removal.

One type of washer used at Navy activities is the Milnor end-loaded, fully automatic washer illustrated in figure 18-2. It is with this type that we are primarily interested in this discussion. The washer is provided with a removable FORMULA CHART which may be easily changed at the operator's discretion. Each formula chart provides a full 88 minutes of operation if desired. Two or even three formulas may be cut on the same formula chart as long as the total elapsed time of the formula does not exceed 88 minutes. Clear visibility is provided for the operator to view the formula during operation. Marker labels affixed to the formula indicate the operation in progress and which supplies are needed when the timer signals.

The washer is also equipped with a Miltrol timer, which will carry the washer through a complete cycle in accordance with the formula cut in the chart, accurately and automatically filling, dumping, maintaining proper water level, supplying proper water temperature for each operation and signaling the operator each time supplies are required, and at the end of the washing cycle.

The washer has an automatic supply injector unit which consists of five compartments. Various supplies are placed in these compartments at the start of the washing cycle. And, at the proper moment the supplies are flushed from the compartment into the washer. The compartments are numbered 1 through 5, starting at the front of the washer.

The two supply compartments nearest the front of the washer (compartment Nos. 1 and 2) are intended to starch, dry soap and/or alkali. Any dry additive normally used in suds baths (such as regenerator, etc.) may also be injected from compartments 1 and 2.

The three remaining supply compartments (compartments 3, 4 and 5) are intended for supplies such as bleach, sour (acid), and blue.

Machines equipped with automatic supply injection may be operated automatically at any time without the automatic injection feature by merely changing formula charts. If desired, two

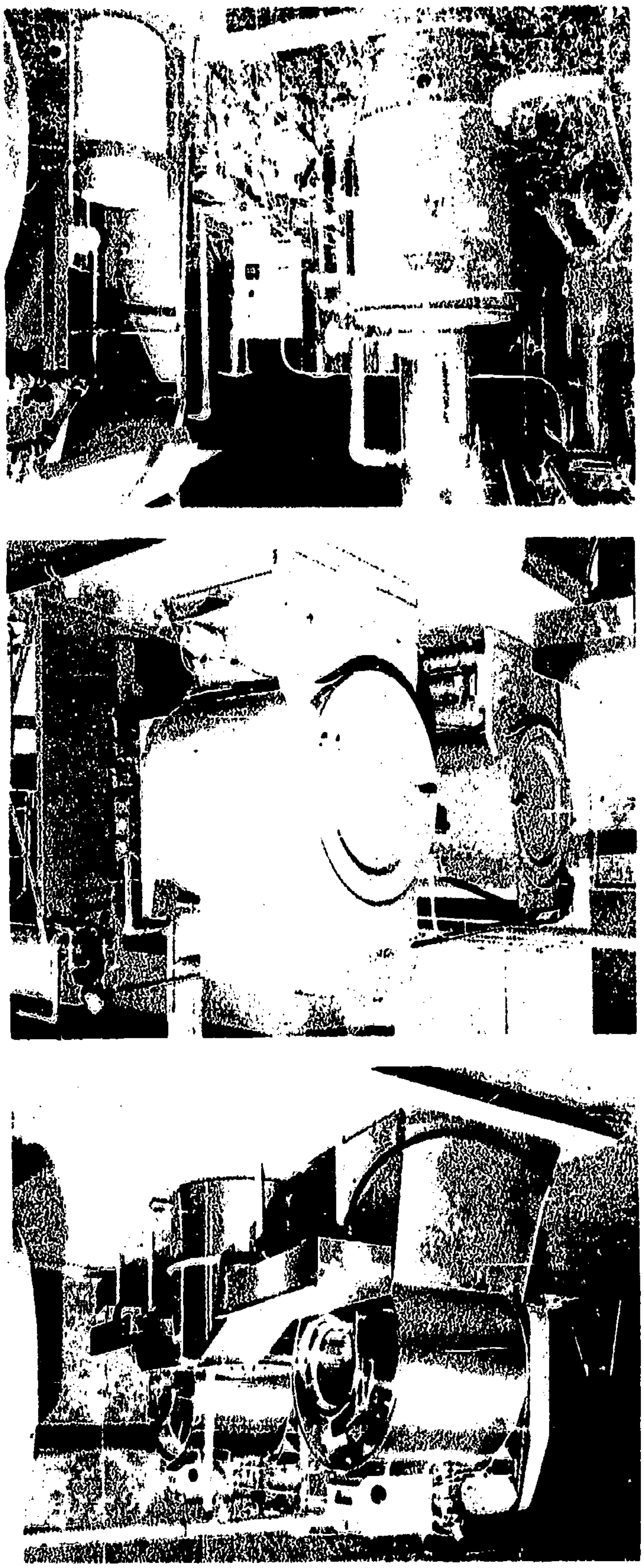

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Figure 18-1. — Skid-mounted laundry unit.

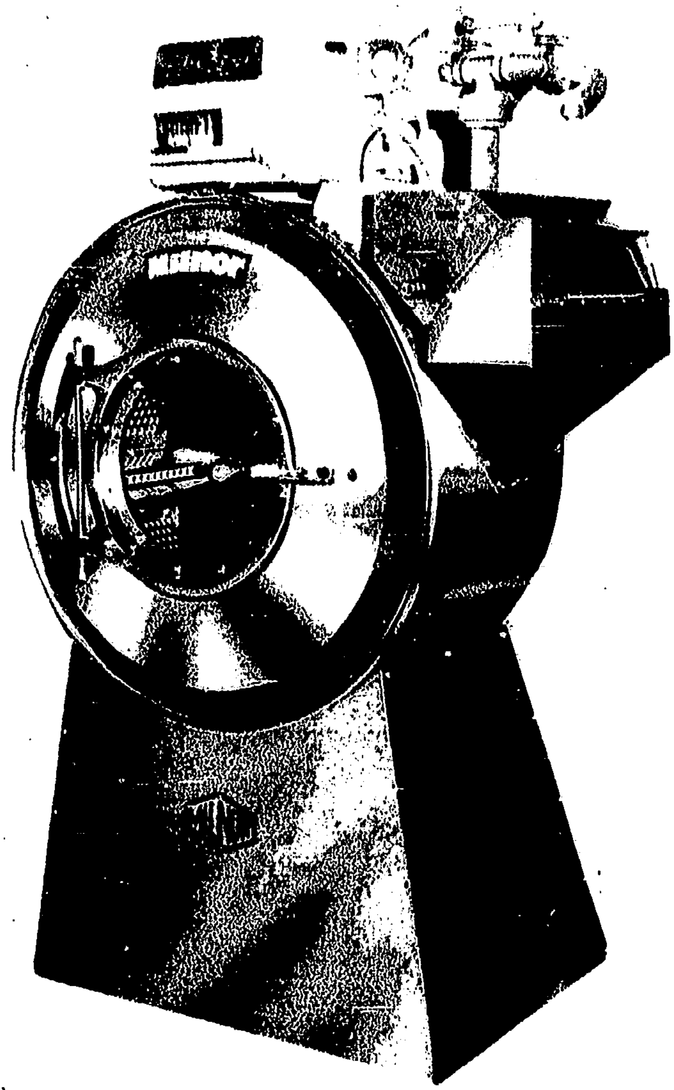

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Figure 18-2. — Washer.

formulas — one using automatic injection and the second without automatic injection — can be cut on the same formula chart, and the machine operated with or without injection.

Machines equipped with automatic supply injection may also be operated manually at any time. To operate manually, however, it is necessary to turn the chart to an uncut position.

When required, Milnor washers can be supplied with an electrically operated tempering control to thermostatically control the water temperature admitted to the washer. This automatic device consists of the necessary circuit and a control thermostat mounted in the discharge from the hot and cold water valves. The thermostat senses the mixture temperature and alternately opens and closes the hot and cold water valves, thus maintaining a rather accurate control of the temperature of the water being admitted to the washer. A point to note is that, since the thermostat senses the temperature of the incoming water rather than the temperature of the final bath within the cylinder, the actual final temperature attained will be dependent, to some extent, upon the temperature of the previous operation; hence, if thermo (hot) water is admitted to the washer after a hot operation, thermo water temperature will tend to be somewhat hotter than the temperature set on the thermostat. Conversely, if thermo water is admitted into the washer after a cold bath, the final temperature will tend to be somewhat colder.

Milnor washers, when required, can be furnished with a device which will automatically inject supplemental steam when called for by the formula chart and for the purpose of raising the water temperature above that which is available from the hot water source. This device also can be operated to ensure the maintenance of a minimum hot water temperature in the washer during periods when the normal hot water source is not able to generate sufficient hot water to keep up with the hot water demand of the plant, or to raise the water temperature near the boiling point. Washers furnished with this device are equipped with an automatic steam injection valve and diffusing nozzle, and with a temperature sensing thermostat mounted in the shell of the washer for the purpose of controlling the final temperature attained.

The thermostat may be adjusted at will and is provided with temperature markings on the adjusting dial. These temperature markings are approximate only and it will be found that the actual temperature attained within the cylinder at the expiration of steam injection will vary approximately 10 degrees from the setting of the thermostat. Consequently, these thermostats should be set by referring to the thermometer furnished on the washer.

INSTALLATION

When installing the Milnor washer, follow the general instructions below.

Install the washer on a steady, level floor or foundation. Make sure the machine is properly bolted down to prevent vibration. A point to keep in mind is that when pushing or moving the washer to its foundation, always push against solid parts of the machine, such as the shell or base—never against the belt guard, valves, electric controls, and so on.

Now assemble the water inlet valves on the rear shell of the washer. (The water inlet valve assembly and two water inlet valve strainers are shipped inside of the washer.) Assembling the inlet valves consists of plugging in a twist-lock connection to the rear of the Miltrol timer, or plugging bullet connectors into rubber sleeves where indicated on the inside of the Miltrol box (depends on model). Incidentally, on some models, the inlet valves are permanently attached and wired to the control, and hence do not require installation.

Connect the hot and cold waterlines to the hot and cold water inlet valves. (The water valve is on the left, and the cold water valve is on the right when facing the front of the washer.) Install one of the strainers in each of the waterlines just ahead of the solenoid valve. Strainers must be installed with the direction of the flow of water in the same direction as the arrow on the strainer. Note that some machines have water valves which require no strainers; consequently, when this type of valve is used, there will be no strainers shipped inside of the washer cylinder.

Some models will be furnished with a "Steam Boil" circuit whereby any or all of the washing operations are done at boiling temperature. In such cases, connect the steam line to the steam solenoid valve which is located near the bottom of the washer shell at the rear of the machine.

To eliminate water hammer when the inlet valves close, the inlet valves may be connected to the water main with a short piece of rubber hose (about 15 to 24 inches long) between the water main and the upstream side of the strainers. The elasticity of the rubber hose will prevent the pounding noise that might otherwise occur every time an inlet valve is closed.

Water inlet valves are rated to handle a maximum of 90 psi pressure, and a pressure reducing valve should be used to limit your water pressure if the pressure exceeds this figure. The steam valve (when furnished) is rated to handle a maximum of 110 psi pressure, and a pressure reducing valve should be used to limit your steam pressure if it exceeds this figure.

Connect the pressure supply for the automatic drain valve to your air line or to the cold waterline. The automatic drain valve requires a minimum of 25 psi pressure AT ALL TIMES. Since the water pressure in a pipe adjacent to a valve always drops when the valve is opened, you must connect the drain valve water connection to the cold waterline at a point as far as possible ahead of all the water inlet valves. If the drain valve opens each time a water inlet valve is opened, your water pressure is insufficient. The water consumption of other machines in your plant will also cause the automatic drain valve to malfunction. Sometimes, but not always, the effect of low water pressure can be eliminated by installing a small, sensitive check valve directly ahead of the strainer in the automatic drain valve pressure connection line. In addition, some Health Board regulations may require that a check valve be installed at this point. If it is impossible to correct your water pressure, the drain valve may be operated by air pressure.

NOTE: Some models may be equipped with electric drain valves which require no air or water pressure connection.

Connect the drain line to the connection in the BOTTOM of the automatic drain valve. The threaded connection in the side of the automatic drain valve is a cleanout hole only.

Carefully check the washer nameplate to make sure that electrical specifications conform with electrical service in your plant. Have a Construction Electrician connect the terminals marked "LINE" in the Miltrol Timer to the powerlines in your plant. It is not necessary to run a secondary voltage to the machine to operate the automatic controls. The Miltrol Timer operates on the same input voltage as the rest of the machine (motor, reversing control, etc.). and has been wired completely at the factory.

The Miltrol Timer is equipped with a step-down transformer to lower the voltage at the contact fingers to 24 volts. Some electrical components in the timer operate on 24 volts (the lamps, timer relays, water valves, etc.). Other electrical components operate on the same voltage as the motor (such as the reversing control contactors and cam timer, the dump valve, and others). You may refer to the wiring diagram pasted in the top of the timer box to determine on which voltage a particular electrical component operates.

It is advisable that a line disconnect switch be provided for each washer, so that any washer in your installation can be turned off for repairs without affecting the operation of the others.

Adjust the level control for the desired high and low water levels. A high and low level will probably be recommended by the manufacturer, and the level control set at the factory to deliver approximately the recommended water depths. However, the final adjustment must be made in the field.

On machines equipped with gear box drives, consult the special instruction sheet for details regarding the care of the gear box before running the washer.

It is also necessary to connect the supply injector unit to a source of water for flushing purposes. The connection is made directly from the waterline to the pressure regulator at the rear of the machine. Always use at least as large a pipe as the pressure regulator connection. Use one size larger if the pipe run is more than 5 feet. If the water piping for the supply injector is too small, the supply injector will not flush the supplies very well. Furthermore, small pipes will magnify water hammer when the supply injector valves shut off, and will cause premature failure of the rubber valve seats in the supply injector valves.

If available, hot water should be used for flushing purposes—providing your hot water source is dependable, has at least 20 psi pressure, and does not occasionally boil over and produce steam in your hot waterline. If hot water is not available, it is permissible to use cold water.

There are five solenoid valves located within the supply injector. These valves can handle a maximum of 30 psi. They are adequately protected against higher pressures by the pressure reducing valve which has been properly set at the factory to deliver between 25 to 28 psi. Increasing the pressure above 28 psi may cause the flush valves to fail to open and may even cause the electric coils therein to burn out. Be sure to check the pressure gage and reset to 25 to 28 pounds, as vibration and/or handling in shipment may cause the regulator to get out of adjustment. Do not exceed 28 pounds pressure. Check by causing a supply injector valve to open two or three times, then setting pressure when there is no flow of water through the supply injector.

Note that under certain peculiar and infrequent combinations of incoming water pressure and upstream piping configurations, the supply injector pressure regulator may chatter while flushing supplies into the machine. Should this occur, check the injector pressure gage to make sure the regulator is set for 25 to 28 psi where there is no flow of flushing water through the unit, and reset if necessary. If the condition persists, remove the pressure regulator and reinstall approximately 10 feet further "Upstream."

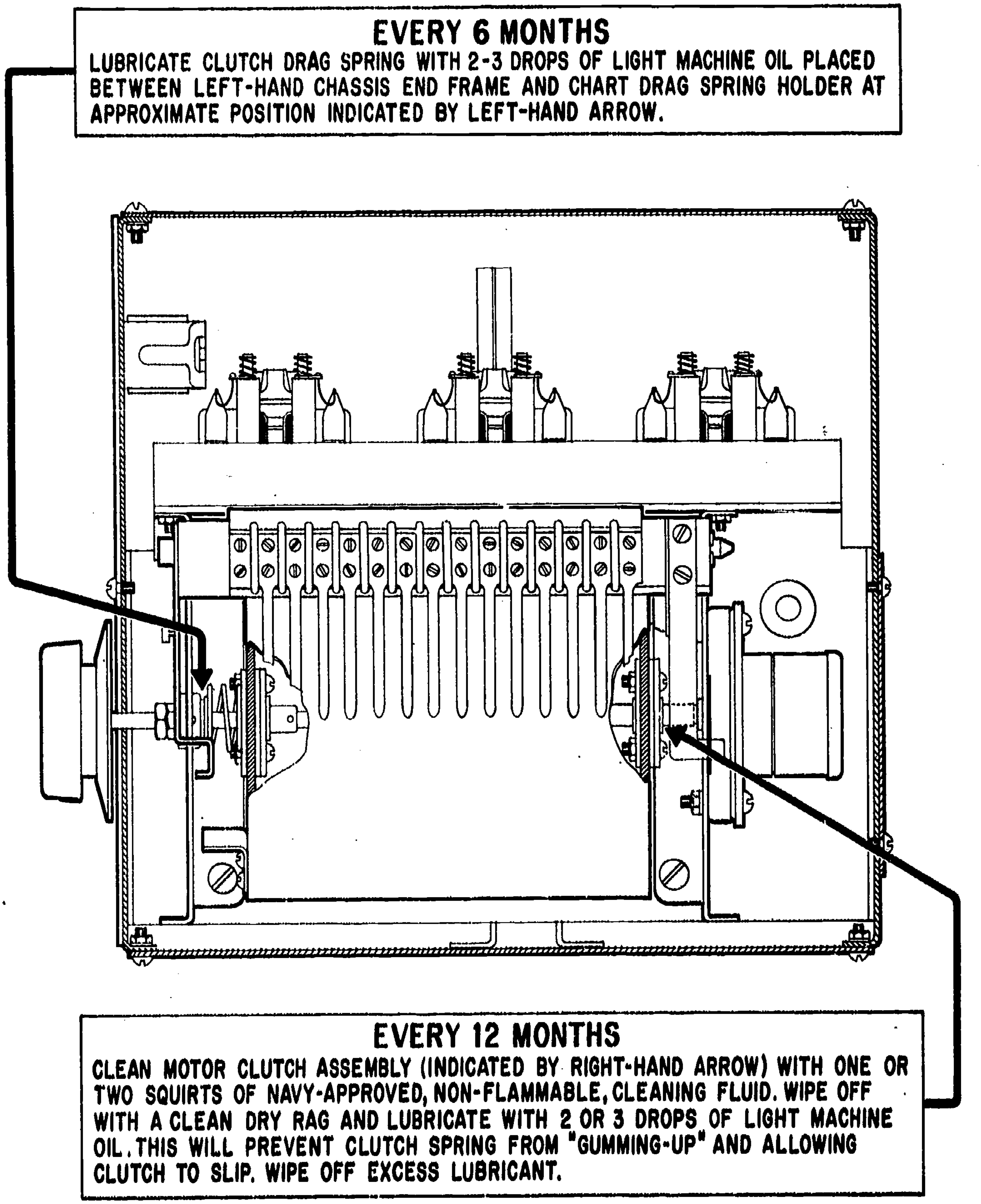

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Figure 18-3. — Lubrication and cleaning points on Milltrol timer.

The tubing connection in the bonnet of the regulator is a bleed-off line that allows the regulator to bleed itself should foreign matter, or a worn seat, permit seepage through the regulator (which would otherwise permit the pressure to the valves to slowly build up and exceed their maximum pressure rating).

MAINTENANCE AND REPAIR

The washer should be inspected at regular intervals to ensure that it is in proper working order. If an inspection reveals that adjustments or repairs are needed, they should be made promptly. Some of the important items to be covered in an inspection are as follows:

1. Ensure that the machine is level.
2. See that all bolts, nuts, and screws are tight.
3. See that latches on cylinder doors are operating properly.
4. Make sure that thermometers are accurate.
5. Check switches to see that they are properly adjusted and working correctly.
6. Ensure that timers are in good working order.
7. Check water level gages to determine if they are correct.
8. See that all electric controls are functioning.

Every two months, check the gear box oil level and replenish with fresh oil, if necessary.

Drain the gear box and replenish with fresh oil once per year. The drain plug in the bottom of the gear box has a small magnet embedded in its end to attract any metallic particles in the oil. Be sure to clean off the magnet each time the gear box is drained and before reinserting the drain plug.

Every 6 months, lubricate the clutch drag spring with 2 or 3 drops of light machine oil placed between the left-hand chassis end frame and the chart drag spring holder, at the approximate position indicated by the left-hand arrow in the chart shown in figure 18-3.

Every 12 months, clean the motor clutch assembly (indicated by a right-hand arrow in the chart shown in figure 18-3) with 1 or 2 squirts of Navy-approved nonflammable cleaning fluid. Wipe off with a clean dry rag and lubricate with 2 or 3 drops of light machine oil. This will prevent the clutch spring from "gumming up" and allowing the clutch to slip. Wipe off excess lubricant.

TROUBLESHOOTING

The washer is a rugged machine, but from time to time you can expect troubles to occur. The information below will aid you in locating the source of various troubles in Milnor washers.

POWER FAILURE:

Complete power failure is easily recognizable because it will cause all electrical components to stop operating immediately. A partial power failure, however, will affect only certain parts of your machine and would probably be caused by a broken wire or defective switch. With the aid of a simple voltmeter or test light and the wiring diagram contained in the Miltrol, you should determine exactly where you "lose" voltage. Start probing at the point of power input, terminals 1 and 2 in the rear of the Miltrol, and work toward the portion of the Miltrol circuit that deals with the particular mechanisms that are not working. If the washer basket turns but nothing else in the Miltrol operates, it is probable that the voltage is lost at the power transformer in the Miltrol. This would indicate if there is a voltage on the primary side but none on the secondary side.

DRAIN VALVE FAILURE CHECK LIST—DRAIN FAILS TO CLOSE (AIR- OR WATER-OPERATED DRAIN VALVES):

a. Master Switch turned "OFF".
b. Drain Switch at "OPEN".
c. Drain finger not touching the timer cylinder screen or touching it at a dirty or greasy spot.
d. The interior light is not lit—this may indicate that the drain relay is not working.
e. The drain relay is working but the contacts are dirty.
f. The pilot solenoid valve is not operating—place your hand on top of it to feel the motion inside. You may have no voltage here, or the valve piston may be stuck.
g. Insufficient air or water pressure to operate the drain valve. Valve requires a minimum of 25 lb pressure. The pressure regulator ahead USING WATER TO OPERATE YOUR DRAIN VALVE, IT IS ABSOLUTELY NECESSARY THAT YOU OBTAIN YOUR WATER FOR THIS PURPOSE AHEAD OF ALL WATER INLET VALVES IN YOUR PLANT.
h. Piston cup in need of replacement.

DRAIN VALVE FAILURE CHECK LIST—DRAIN FAILS TO OPEN:

a. Clogged exhaust line from the pilot valve to soap chute. Every time the drain switch is opened, air or water, as the case may be, should emit from the exhaust line into the soap chute.

b. Rusted or broken spring in the drain valve itself.

c. Dented drain valve cylinder.

d. Faulty pressure regulator allowing water or air in excess of 40 psi to enter the pilot solenoid drain valve.

WATER VALVE FAILURE CHECK LIST—WATER VALVE FAILS TO OPEN:

a. Master switch turned "OFF".

b. Appropriate water switch turned "OFF".

c. Water finger not touching the timer cylinder screen or touching it at a dirty or greasy spot.

d. Drain valve is open. It is impossible to admit any water into the washer with the drain valve open.

e. Valve is not operating electrically due to broken wire in the leads that go to the inlet valves, or shorted coil in water valve.

f. Pilot orifice in inlet clogged with foreign matter.
g. Build up of lime or similar deposit on inlet valve piston causing it to bind.
h. Excessive water pressure (frequently encountered in plants using steam to heat water in "instantaneous" water heaters).
i. Water level control is not operating due to the float binding in the chamber. The float chamber may become coated with soap residue, lint and lime deposit.
j. Switches inside the level control are not operating—either they are faulty or, are not being depressed. Move the float rod to its extreme positions to see if the switches click.
k. Extremely low water pressure.
l. Dirty strainers in the water inlet line.

WATER VALVE FAILURE CHECK LIST—WATER VALVE FAILS TO CLOSE. WASHER OVERFLOWS:

a. Short or ground in the water valve coil. Turn power off to close the valve.

b. Water pressure is extremely low.

c. Piston return spring in the valve is broken.

d. Piston or the pilot orifice in the piston is clogged by foreign matter.

e. Pilot orifice seat in the water valve piston eroded or prevented from shutting off fully by foreign matter (will also cause valve to leak).

f. Clogged float chamber in the level control.

g. Cracked or faulty float in the level control.
h. High and low level adjusting collars on the float rod set too close together.

TIMER CYLINDER DOESN'T TURN:

a. Master Switch not at "FORMULA".
b. Water level not attained. Timer will stop until the selected level is reached.
c. Improper switch position for Zero Level Starching. For Zero Level Starching on Model E Miltrols, the master switch must be at "FORMULA" and the drain switch at "SHUT".
d. A loose setscrew on the clutch which joins the timer motor shaft to the time cylinder. (Consult the manufacturer's instruction manual.)
e. No voltage at the timer motor. Skin the insulation back slightly on each motor lead to check the voltage. Be certain to tape the skinned wire when finished.
f. If it is necessary to replace the timer cylinder motor, replace BOTH THE MOTOR AND GEAR CASE, NOT JUST THE MOTOR ALONE.

WASHER CYLINDER RUNS BUT NO PART OF AUTOMATIC CONTROLS FUNCTION:

a. Defective transformer.
b. If the signals operate, the drain relay is faulty, or the drain finger is not in contact with the timer cylinder screen.
c. Drain switch at "OPEN".

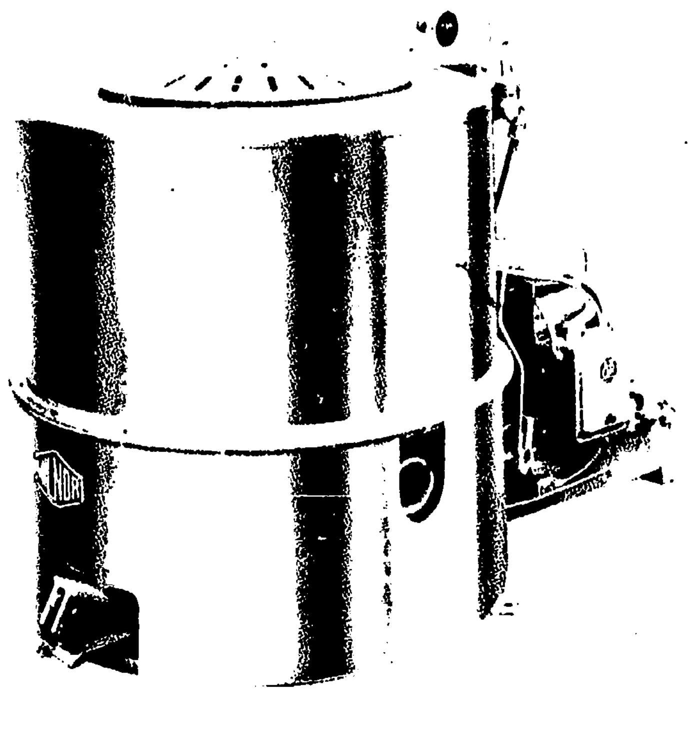

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Figure 18-4. — Extractor.

MILTROL OPERATES BUT DOES NOT RUN -- OR RUNS IN ONE DIRECTION.

a. Faulty reversing control timer motor.
b. Reversing control contactor coil burned out.
c. Faulty microswitch on reversing control cam mechanism.
d. Low voltage.
e. Broken wire.
f. Signal relay contacts dirty, or faulty signal relay.

EXTRACTOR

The purpose of the extractor is to extract water from clothes after rinsing. The extraction of the water is accomplished by spinning the clothes at a high speed, applying centrifugal force, pushing the water to the outer surface and discharging it through small holes in the basket of the extractor to drain. Figure 18-4 shows a Milnor extractor, which is one type you may often see in use at Navy activities. Milnor extractors are available in three models: GSM-4-20, GSM-3-26, and GSM-3-30. These extractors may be equipped with a manual brake or an automatic brake. An assembly drawing of a Milnor stainless steel extractor is shown in figure 18-5.

INSTALLATION

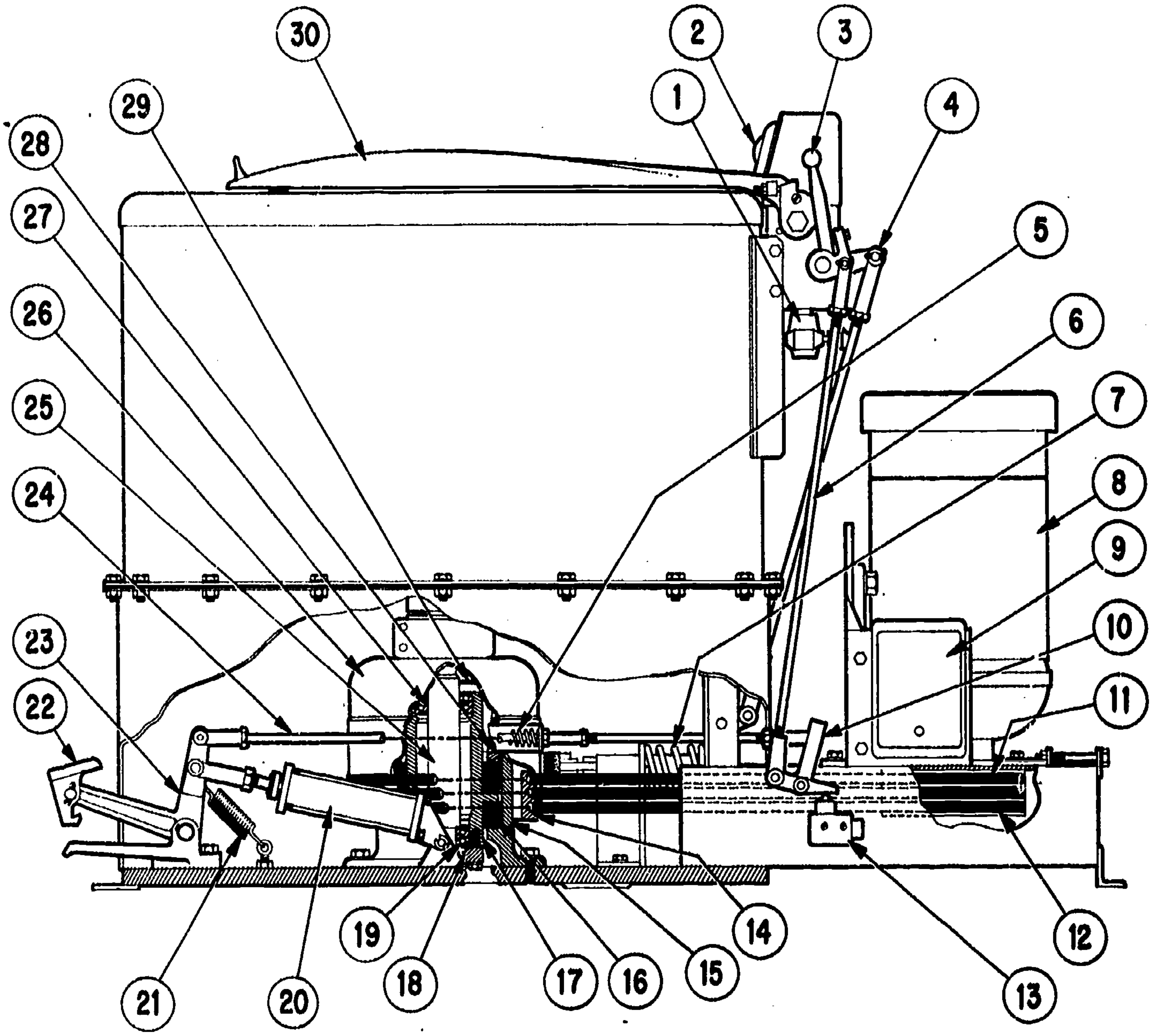
The procedure for installing extractors will vary with different makes and models of extractors. The instructions given here apply to the Milnor extractor, models GSM-4-20, GSM-3-26, and GSM-3-30. Either of these machines may be installed on any good floor or foundation and will operate without excessive vibration if properly leveled and bolted down.

When installing the extractor on a concrete floor, carefully lower the machine over the foundation bolts, taking care that the threads of the foundation bolts are not damaged. Support the extractor by the base and side rails so the three bolt-down pads and rear bolt-down angle are approximately 1" above the foundation. Lightly grease the three holddown bolt pads and rear angle to permit the machine to be jacked up off the grout pads without damaging the grout. CAREFULLY AND THOROUGHLY WORK THE GROUT UNDER THE HOLDDOWN PADS AND REAR ANGLE TO ENSURE 100% CONTACT BETWEEN THE GROUT AND THE HOLDDOWN PADS AND THE GROUT AND THE REAR ANGLE. (See fig. 18-6.) Do not embed pads or angles to grout. Use a nonshrinking grout such as "Stone Hard," "Embecco," "Pourock" or equal. Make the grout pads approximately 6" square under each of the three holddown pads, and in the rear of the machine, extend the pad approximately 2" past the edge of the angle in all four directions. When the grout is completely cured, jack up the machine and remove the supports under the machine. Carefully lower the machine onto the grout and securely tighten all foundation bolts. DO NOT GROUT UNDER THE BASE. No part of the round base or the motor rails should touch the floor or any of the bolts which may protrude below the base. If any part of the base or motor rails come in contact with the floor, this could cause the extractor to vibrate excessively. Make sure the extractor is reasonably level.

Check the voltage shown on the nameplate for proper electrical specifications.

The 26" and 30" extractors with automatic brake require air pressure to operate the brake air cylinder. Connect the air supply to the 1/4" strainer inlet located at the rear of the machine just below the cover interlock box. Adjust the needle valve to prevent the brake pedal from slamming when it is applied automatically by the air cylinder.

The automatic brake on the 20" extractor is electrically operated and does not require air pressure.



LEGEND:

1. SOLENOID VALVE	11. 3" V BELTS	21. BRAKE RETURN SPRING
2. TIMER (25 Minutes)	12. MOTOR PULLEY	22. BRAKE PEDAL
3. OPERATING LEVER	13. MICRO SWITCH	23. BRAKE LEVER BRACKET
4. INTERLOCK CLEVIS ROD	14. BRAKE PULLEY	24. BRAKE ROD
5. BRAKE PRESSURE SPRING	15. PEDESTAL	25. SPINDLE
6. SWITCH LEVER ROD	16. RUBBER MOUNTING	26. BRAKE
7. INTERLOCK RETURN SPRING	17. BEARING HOUSING	27. UPPER BEARING
8. MOTOR	18. BOTTOM BEARING CAP	28. PACKING NUT
9. MAGNETIC STARTER	19. LOWER BEARING	29. RUBBER WATER BARRIER
10. BELL CRANK	20. AIR CYLINDER	30. COVER

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Figure 18-5. — Assembly drawing of Milnor stainless steel extractor.

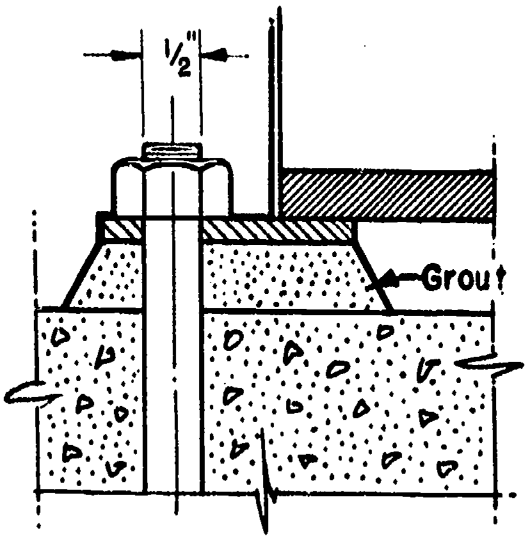

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Figure 18-6.—Grout.

The extractor may be drained from either the right-hand or the left-hand side. Be careful in connecting the drain pipe to make sure that the stainless steel coupling is not torn out of the bottom of the extractor. If a rigid connection to the drain is utilized, the extractor must be bolted down and must not be allowed to vibrate. It is best to use a short piece of flexible hose in the drain line near the extractor; otherwise, vibration might cause the drain coupling to be cracked out of the bottom of the extractor.

Have a Construction Electrician connect your motor to the power supply. An extractor motor draws very high current for extended periods of time during starting. It is therefore necessary to use much larger wire and line fuses than average motor applications. The machine should be wired and fused in accordance with the recommendation on the tag attached to the machine. While you may find local peculiarties, the recommendations will suffice in most cases. A fused line disconnect switch should be installed, and this is not provided by the manufacturer.

Be sure that the rotation of the basket is clockwise, as shown on the nameplate.

It is recommended that the extractor be thoroughly grounded through the grounding lug which is provided on the motor. Have the Construction Electrician run a ground wire from the lug to a steam or water pipe in your plant.

After installation, thoroughly clean the inside of the basket to remove the dust and grime which may have accumulated during shipment.

MAINTENANCE AND REPAIR

If the extractor is to give satisfactory service over the longest period of time possible, it should be properly maintained and repairs be made promptly when needed. Information on the maintenance and upkeep of the Milnor extractor is given below.

The extractor rubbers should be checked at regular intervals to ensure that they are in good condition. When necessary, the rubbers should be tightened or replaced. To tighten the rubbers, simply remove the packing lock and turn the packing nut clockwise using a spanner wrench provided by the manufacturer.

To replace the extractor rubbers, remove the curb assembly. Now remove the basket from the spindle. The basket is held to the spindle with a locknut on the inside of the basket, and the shaft and basket are fitted together with a taper. The basket may be removed from the spindle by "jolting" it off of the spindle or, if the extractor has been in service a long time, it may be necessary to press the basket off of the spindle. Next, remove the pulley, loosen the packing nut, and remove the bearing housing assembly with its shaft and bearings, after which new rubbers may be installed and the extractor assembled in the reverse order. When installing new rubbers, be sure to place the flat face of the rubbers so they face the flange on the bearing housing—this will ensure that the concave side of the rubbers will be down on the lower rubber, and up on the upper rubber.

Ensure that the extractor is lubricated at all lubrication points recommended by the manufacturer. Also, use those lubricants approved by the manufacturer. As for frequency, use one stroke of lubricant every 30 days or as experience dictates. Note that shaft bearings are packed at the factory and do not require greasing.

TROUBLESHOOTING

In troubleshooting the extractor, it is important that you be able to recognize common troubles, and know the possible causes of the troubles. Obviously, a lot of time may often be saved if the cause is determined before any corrective action is started. The information below will be useful to you as a guide in locating the sources of various troubles in Milnor extractors.

MOTOR FAILS TO START (All 20" Models and 26" and 30" Manual Brake Machines):

a. Check for power failure.
b. Line fuses blown out.
c. Overload relay tripped. Wait 5 minutes and push reset button on magnetic starter.
d. Loose connection in wiring.
e. Microswitch in aluminum switch box is not actuating properly. Check linkage to cover interlock lever and manual footbrake (if applicable).

MOTOR FAILS TO START (26" and 30" Automatic Brake Machines):

a. Interlock switch faulty, or not being actuated by bellcrank.
b. Piston cup in brake air cylinder binding, preventing free motion or piston.
c. Brake locked "VN" manually.

MOTOR RUNS BUT MACHINE FAILS TO COME UP TO SPEED:

a. Load not properly balanced.
b. Low voltage and/or frequency.
c. Loose connection in switch or wiring.
d. One fuse blown (3 phase).
e. Dirty or worn brushes on commutator (single phase).
f. Interlock or brakeshoe dragging.
g. Clothes or other material inside crub, jamming basket.
h. Belts loose and slipping.
i. Brake not releasing when extractor turned on.

MOTOR RUNS BUT OVERHEATS:

a. It is probably normal. NOTE: You should not become alarmed if the motor becomes too hot to touch. An electric motor is rated for operation with a given temperature rise (usually 40 to 50 degrees centigrade) over room temperature. Thus, if the room temperature is around 100 degrees Fahrenheit, as is very normal in laundry and dry cleaning plants, a motor rated with a 50 degree centigrade rise may operate at 190 degrees Fahrenheit without affecting its life. The average person cannot keep his hands on an object hotter than about 125 degrees Fahrenheit; therefore, it is easily seen that a motor can get "too hot to handle" without being overheated.)

b. Too many stops and starts per hour, or not enough running time for each load. The motor on the extractor is designed for a maximum of 8 starts per hour, and minimum running time of 6 minutes per load. The maximum of 8 starts per hour includes false starts, i.e., where it is necessary to stop the machine and rebalance the load. This limitation is necessary to allow the motor to cool after each start.

c. Excessively low voltage—caused by overloaded line condition, or low voltage supplied by power company.

BRAKE NOT RELEASING WHEN EXTRACTOR TURNED ON (20" Extractor):

a. Solenoid plunger rod, or other portion of brake mechanism binding. Solenoid plunger must be completely free.

b. Low voltage or frequency.

c. Too much tension on brake pressure spring.

d. Loose connection in solenoid wiring.

BRAKE NOT RELEASING WHEN EXTRACTOR TUNED ON (26" and 30" Extractor):

a. Exhaust port of pilot solenoid valve clogged.

b. Bad microswitch in timer box.

c. Pilot solenoid valve jammed open.

EXTRACTOR MAKES KNOCKING NOISE WHEN RUNNING:

a. Machine not properly bolted to the floor. Feel with your hand around the edge of the base for vibration and movement.
b. Packing nut loose.
c. Spindle pulley loose on spindle. Tighten by means of two draw-down bolts in hub of spindle pulley. Be careful not to tighten excessively.
d. Rubbers worn.
e. Basket loose on spindle. Tighten basket nut.
f. Bas bearings. This is very unusual. Bad bearings may be characterized by heavy whirring and/or rumbling noise similar to the noise made by ball-bearing roller skates. Also check motor bearings.
g. Motor pulley loose on shaft.

EXTRACTOR FAILS TO CARRY NORMAL OUT-OF-BALANCE LOAD

a. Rubbers too loose or too tight.
b. Motor not developing full power.
c. Brake not fully releasing when motor is turned on.
d. Extractor not fully bolted down to the floor.

TUMBLERS

For satisfactory ironing or wearing of clothing and various other articles, the extractor leaves too much moisture in these materials. The machine used in Navy laundries to remove the amount of moisture necessary from different types of materials to ensure good ironing is called the tumbler—or drying tumbler.

One type of tumbler commonly used at Navy activities is the Huebsch Loadmaster model 42" tumbler. This is a commercial-type tumbler with a maximum drying capacity of 100 pounds (dry weight) of laundry per hour. A two motor drive system provides independent fan and cylinder operation. One way cylinder rotation and door safety switch are standard. The instructions below on the installation, maintenance and repair of tumblers applies to the Huebsch Loadmaster model 42" tumbler.

INSTALLATION

When installing the tumbler, make sure it is level and properly secured to the floor. In leveling, use shims of adequate size to avoid weight concentration.

It is important that the dryer room be well ventilated. A 2 sq. ft. opening to the atmosphere must be supplied for each 1,700 cfm model and 4 sq. ft. for each 3,000 cfm model. Allow adequate clearance on all sides for servicing and efficient loading and dispatching of dried materials. Do not overlook clearance for future ductwork, if there is a possibility it might be needed.

Steam Connections

On steam heated laundry tumblers, steam coils are guaranteed to 125 psi working pressure. A minimum of 100 psi should be maintained for efficient performance on laundry tumblers. Connect 3/4" steam supply and return lines to the coils as marked on the coil housing. The inlet is at the top, the discharge at the bottom. Pitch the steam lines for proper draining. Install flexible steam hoses between coils and piping to reduce strain on the coils. Supply each coil bank with shut off valves at the inlet and outlet connections. Locate the steam trap at least 1 ft. below the discharge level of the coil. Install a strainer between the steam coil and the trap. Install a swing check valve after the trap. Use valves and unions to isolate the steam trap, strainer and check valve for ease of replacement or repair. A trap for each coil is recommended for best performance.

Electrical Connections

Laundry tumblers are factory wired for operation and require only power supply connection. Refer to the wiring diagram in the control box lid and connect 3-phase service to posts L-1, L-2, and L-3 in the control box. A fused disconnect should be installed. For multiple tumbler installations, each unit should be equipped with a disconnect switch. Information for fuse size can be found inside the control box cover. Fan and cylinder motors have thermal overload circuit breakers mounted in the control box. Super tumblers have a cylinder motor fuse block in the control box. Have a Construction Electrician make this connection. Check fan rotation.

For maximum efficiency of single or multiple unit installation, air discharge must be ducted individually to the atmosphere by the shortest possible route. Avoid sharp turns. Use sweep elbows for 90° turns. Duct size must be equal to the discharge spout or larger for runs less than 20 ft. For each additional 20 ft. of duct run, increase the entire duct diameter by 1/10 for round duct, or the entire duct area by 1/5 for rectangular duct. A single 90° elbow is equal to adding 16 ft. of 12 in. diameter duct run, or 21 ft. of 16 in. diameter duct run, and the entire duct diameter should be refigured accordingly. For multiple unit installations where common header is absolutely necessary, feeder ducts must enter at a 45° angle in the direction of air flow. Header size must progressively increase at each duct entry to allow for full air flow capacity of all the units. Discharge to the atmosphere must be constructed to eliminate excessive back pressure and to prevent the entrance of weather. It is recommended that 180° sweep elbows of ample size for vertical runs, and 90° sweep elbows for horizontal runs, be used. No caps,

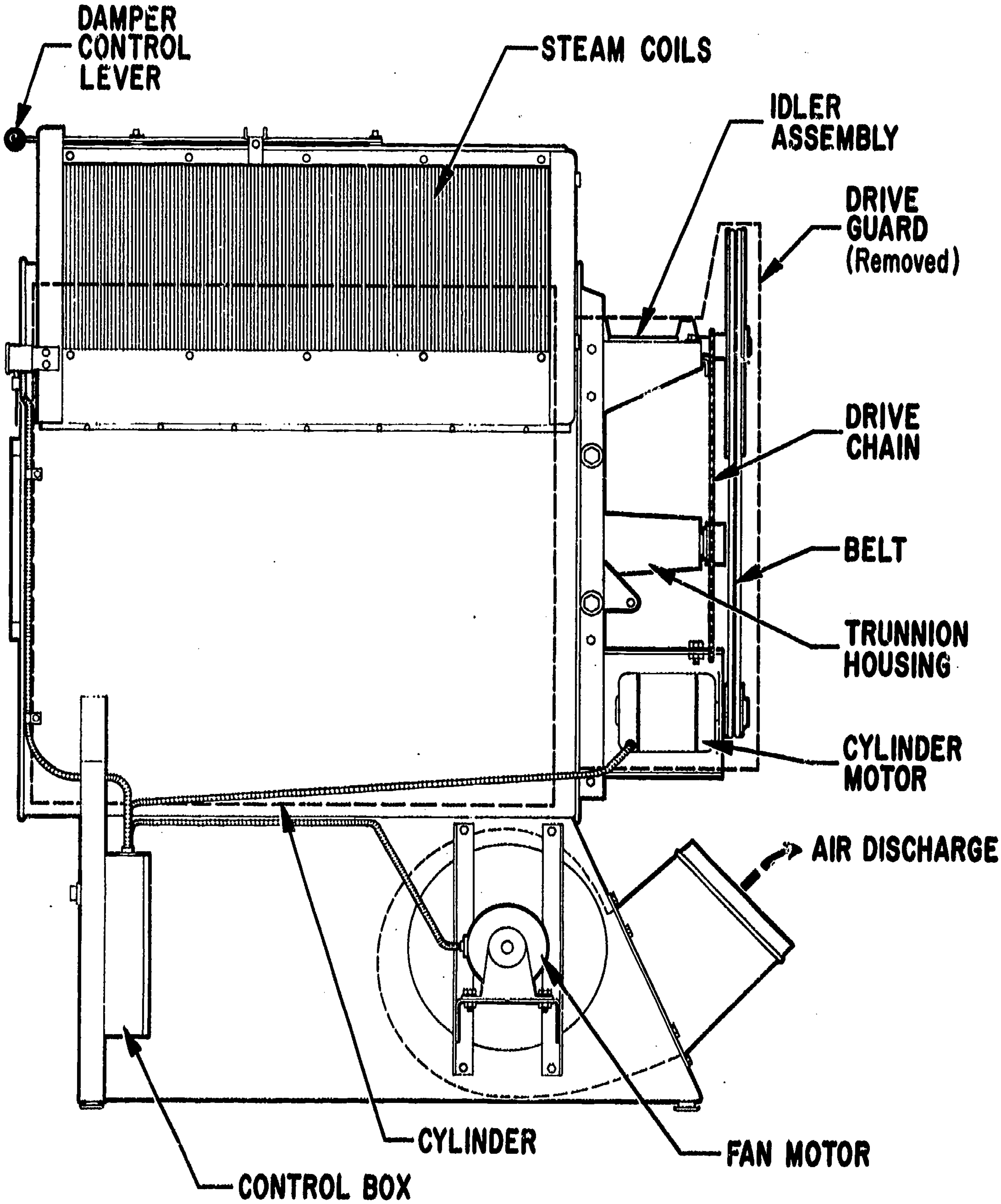

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Figure 18-7. — Right side view of tumbler.

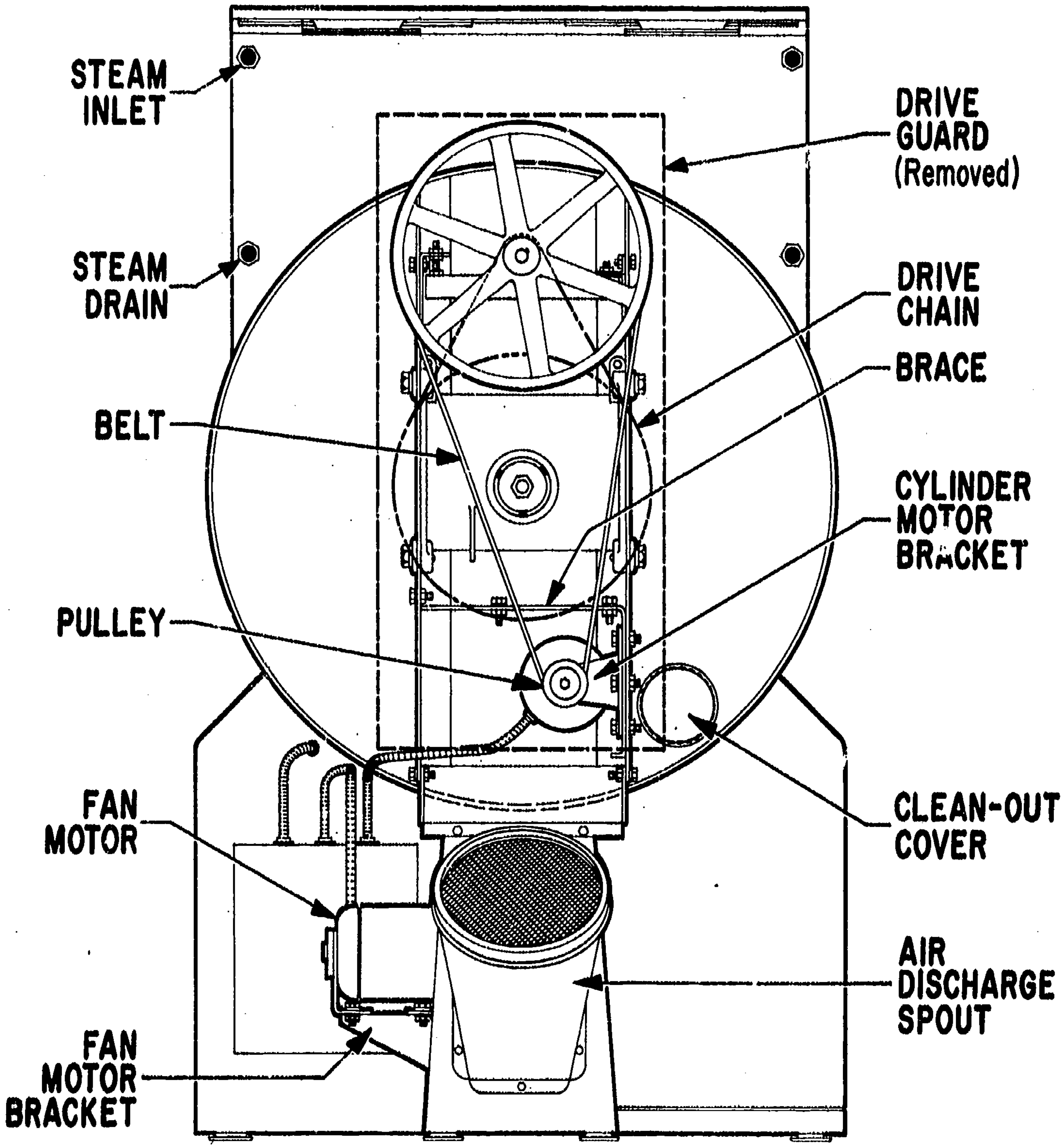

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Figure 18-8. —Rear view of tumbler.

screens, or bags should be installed on the end of the discharge duct. The end of the duct should be at least one diameter away from any obstacle.

Testing

Before placing the tumbler in service, and with the power off, check for correct cylinder, belt and chain adjustment as decribed later in this chapter. Turn the power on and start the tumbler to check the cylinder and fan rotation, and the door switch adjustment. On standard units, the cylinder must rotate clockwise when viewed from the front of the tumbler. The fan must always turn clockwise when viewed from inside the lint drawer housing. Turn the steam on. Place a load of damp rags in the cylinder and run until dry. Check the cylinder adjustment under load and check for vibration or unusual

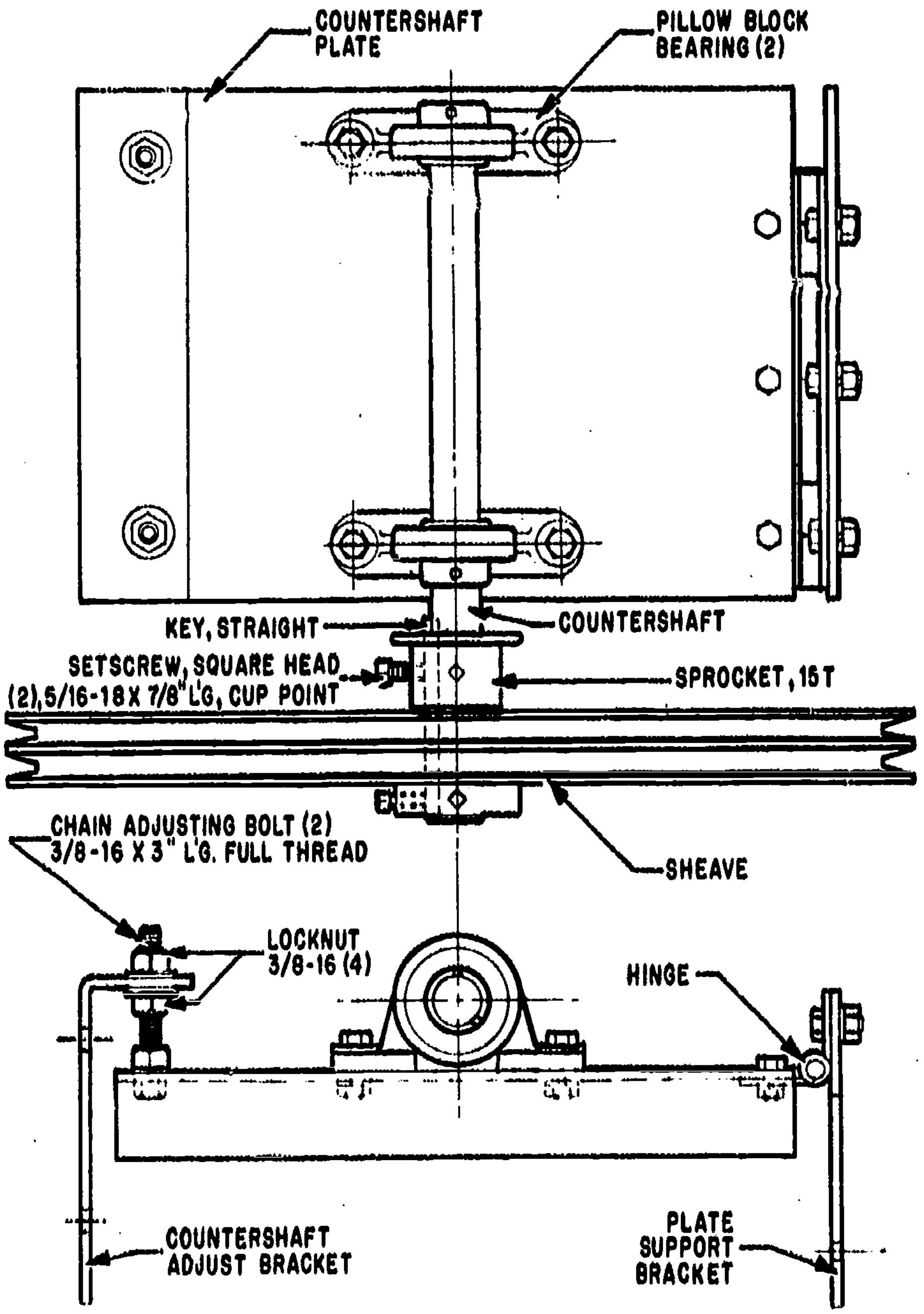

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Figure 18-9.—Idler assembly.

noise. Reversing models must be checked for correct time delay between reversing cycles. Correct any adjustment before placing the tumbler in service.

MAINTENANCE AND REPAIR

A special effort should be made to keep tumblers operating at peak efficiency. Some of the general maintenance and minor repair procedures applicable to the care and upkeep of tumblers are explained below.

Electrical Control Box

Loose wire connections can cause tumbler failure and possible damage. Remove the control box cover and check the controls monthly. Replace the contactor points when pitted or worn. Check and tighten all wire connections, including thermal overload heating coils. Check for secure mounting of controls to the control box. Failure of holding coils, thermal overload circuit breakers or any part of the reversing timer assembly requires replacement. (For detailed information, consult the manufacturer's electrical parts booklet.)

Electric Motors

Ensure that electric motors are removed and cleaned thoroughly at least once a year. All motor repairs should be performed by the Construction Electrician. Frequent tripping of the thermal overload circuit breakers may be caused

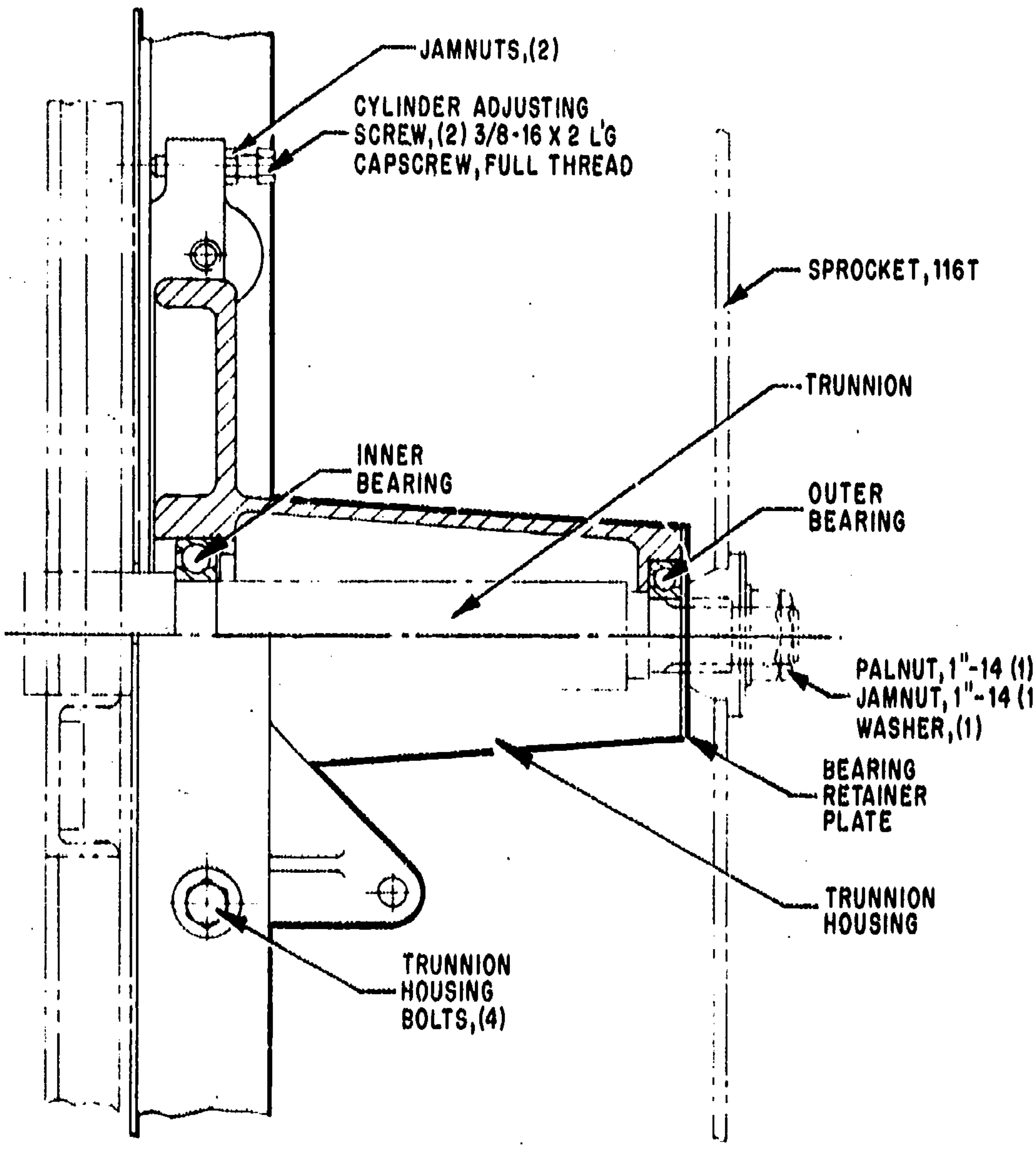

Figure 18-10. — Trunnion housing assembly. 54.357

by low voltage, loose connections, reversed fan or high ambient temperature. Never increase thermal overload heater size without complete investigation.

Electrical Safety Controls

The door switch, thermostat, and other optional electrical equipment requires replacement upon failure. Shut off power and observe all details of mounting and wiring. Mark wires before removal. After exchange, check the wiring diagram before turning on the power. Check with the power on. Adjust if necessary before returning to service.

Adjustments

In servicing the tumbler, it may be necessary at times to adjust the belt, chain, cylinder, reversing timer (on machines so equipped), and door safety switch. To make these adjustments, follow the procedures below.

BELT. — To increase belt tension, loosen the four bolts holding the cylinder motor to the bracket and force the motor evenly downward. (See figs. 18-7 and 18-8.) Tighten the bolts and check alignment with the belts and large sheave, using a square or small level. Check belt tension midway between the motor pulley and the large sheave. Adjust to 1" travel under slight thumb pressure. Check the chain adjustment at the same time.

CHAIN. — This adjustment is controlled through the upward and downward movement of the hinged idler adjusting plate. (See figs. 18-7, 18-8, and 18-9.) The two adjusting screws attached to the adjusting plate are locked to the adjusting screw support bracket with locknuts on both sides of the plate. At this point, all chain adjustments are made. To tighten the chain, loosen the locknuts on top of the support bracket several turns and tighten the bottom locknuts evenly. A good chain adjustment is never banjo tight. Check the chain midway between the large and small sprocket for 1" free travel. Set your adjustment at this point and tighten both adjusting screw locknuts. To loosen the chain, turn the bottom locknuts downward, always evenly. Retighten the top locknuts when correct adjustment has been reached. Check the belt adjustment at the same time.

CYLINDER. — In adjusting the cylinder, remove the two tapered pins locating the trunnion housing to the rear support angles. Do not reuse these pins which are for shipping purposes only. Loosen the four bolts holding the trunnion housing to angles. (See figs. 18-7, 18-8, and 18-10.) Loosen the locknuts on the two adjusting screws located at the upper corners of the trunnion housing. Turning the screws clockwise raises the cylinder, turning counterclockwise lowers the cylinder. Adjust until the distance between the cylinder and loading door flange is equal at all points or slightly greater at the bottom to allow for weight of the load. Tighten the adjusting screw locknuts and trunnion housing bolts securely. Recheck the adjustment before returning to service.

REVERSING TIMER. — On tumblers equipped with a reversing cylinder, check the cylinder rotation with normal load to ensure complete stoppage of the cylinder between reversing cycles. To increase time delay, pull out the black dial located in the center of the timer assembly and rotate clockwise 1/8". The dial is under spring tension and will return to the engaged position when correctly in line. Check the cylinder with the power on and repeat for more delay. Turn counterclockwise to reduce time delay. Never advance more than one notch without checking the cylinder. Power must always be off when the timer dial is being rotated manually.

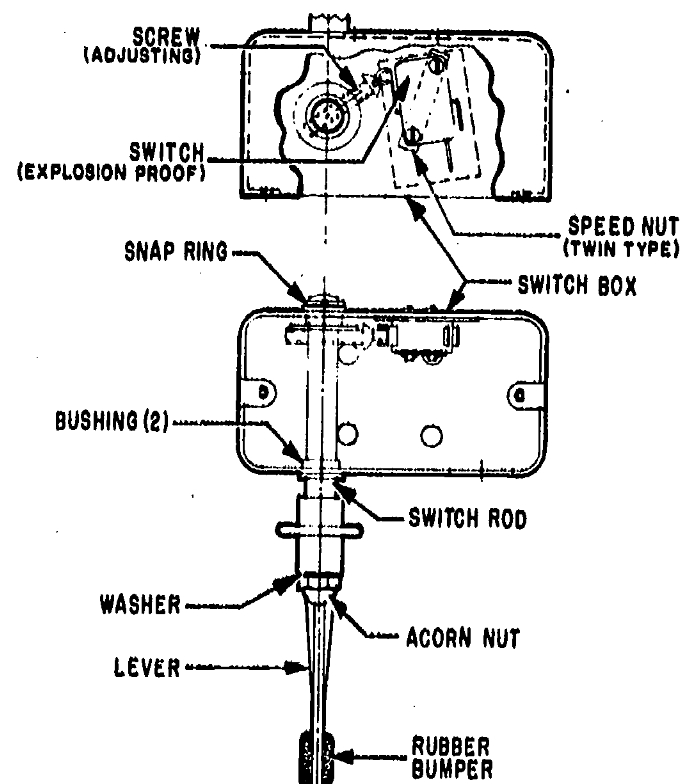

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Figure 18-11. — Door safety switch assembly.

DOOR SAFETY SWITCH.—The door safety switch assembly is preset at the factory to stop the cylinder when the door is opened approximately 6". Repair or replacement may make readjustment necessary. (See figs. 18-8 and 18-11.) To adjust, loosen the nut on the bottom of the switch shaft and loosen the switch lever from the serrated end of the shaft. Rotate the lever toward or away from the tumbler to decrease or increase the door adjustment to the 6" operating point. Retighten the lever and nut.

Lubrication

Once a month, remove the circular cover on the drive guard and oil the chain, using SAE-30 oil. The pillow block, trunnion, and motor bearings are sealed and require no service.

STEAM GENERATOR

The purpose of the steam generator is to provide sufficient steam to operate both tumblers, as well as to provide a continuous supply of hot water to both washers under constant operation. One type of steam generator frequently used in laundries at Navy activities is the Clayton steam generator, model RO-33-PL. It is with this type of generator that we are concerned in this discussion.

The Clayton steam generator is a water-tube boiler and will deliver its rated output of 99 percent quality steam (containing less than 1 percent moisture) per hour from 60° F feedwater. The generator will develop its full rated pressure within 5 minutes from a cold start.

The generator features a continuous circulating water feed system with a constant capacity pump which ensures a wet tube in the generator heating unit at all times. Automatic controls regulate the feed-water rate and modulate or stop the burner in accordance with steam demand. Standard equipment includes safety devices for protection against water failure, burner failure, excessive pressure, and electrical overload.

A flow diagram of the generator's water and steam circuit is shown in figure 18-12. Supply water enters the feed-water section of the water pump from the hotwell/feed-water tank, and is pumped directly to the steam accumulator. The circulating liquid is drawn from the accumulator by the circulating section of the water pump and pumped into the single passage heating coil, and then back to the accumulator where the steam 's separated.

The pump is directly driven by an electric motor and contains no packing boxes. It is arranged in two sections—the feed-water section and the circulating section. The pump disphragms ar operated hydraulically by oil displaced by reciprocating pistons within the pump. A built-in, solenoid-operated bypass valve is incorporated on the hydraulic pressure section of the feed-water pump to prevent the feed-water section from pumping when the valve is open. The valve is actuated by the water level control in accordance with liquid level in the accumulator.

INSTALLATION

When installing the boiler, careful consideration should be given to fuel, water, electrical, and venting facilities. Ample clearance should be allowed on all sides to facilitate operation and maintenance.

Use shims, if necessary, to prevent distortion of the frame when drawing down foundation bolts.

When installing external piping, use pipe unions adjacent to the boiler connections to allow easy removal of parts for inspection and cleaning.

Fuel Requirements

The boiler is equipped to burn No. 2 diesel fuel oil. Make connnections as follows:

Connect the fuel supply line to the inlet connection on the fuel filter. If the fuel supply tank is located above the fuel pump, install a shutoff valve in the supply line at the filter inlet. If the fuel tank is below the fuel pump (maximum lift 10 ft.), use 3/8-inch minimum pipe size with a check or foot valve installed in the supply tank. In this case, install a swing check-valve at the fuel filter instead of a shutoff valve to further ensure against loss of prime. Frictional losses on long runs of pipe will materially reduce the 10-ft. maximum suction lift of the fuel pump previously mentioned.

Note the fuel suction line must be an individual line from the fuel tank, and all air leaks and air pockets must be eliminated to avoid erratic burner operation.

Connect the return line to the return connection below the fuel pump. The return line must be a separate line back to the fuel tank and NOT connected to the fuel suction line. This

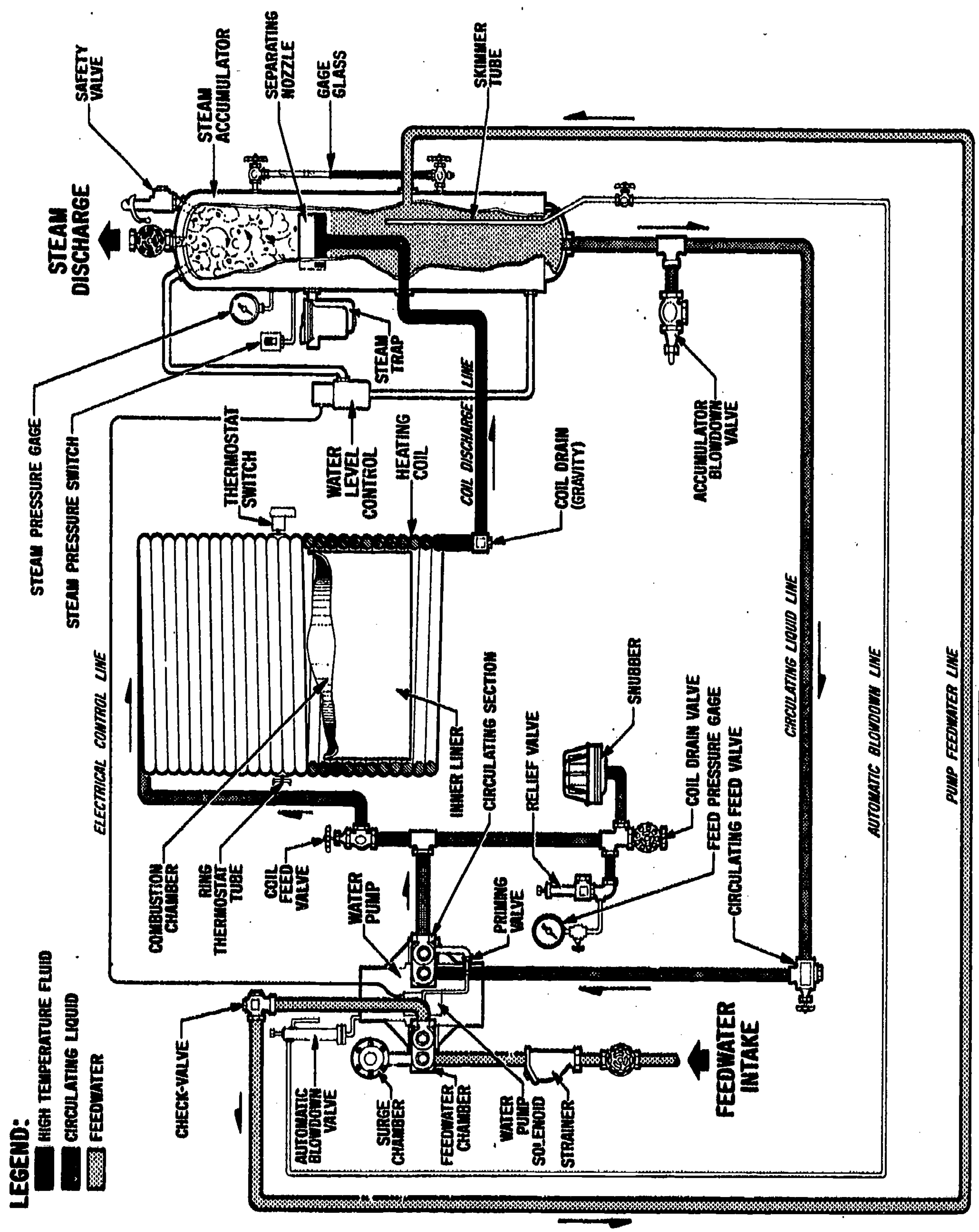

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Figure 18-12. —Flow diagram of generator's water and steam circuit.

will prevent locking of air in the fuel system which would cause erratic burner operation.

CAUTION: Do not install a shutoff valve in the return line. A swing check-valve may be installed if the fuel pump is below the fuel tank. IMMEDIATE DAMAGE to the fuel system will result if the return line is closed.

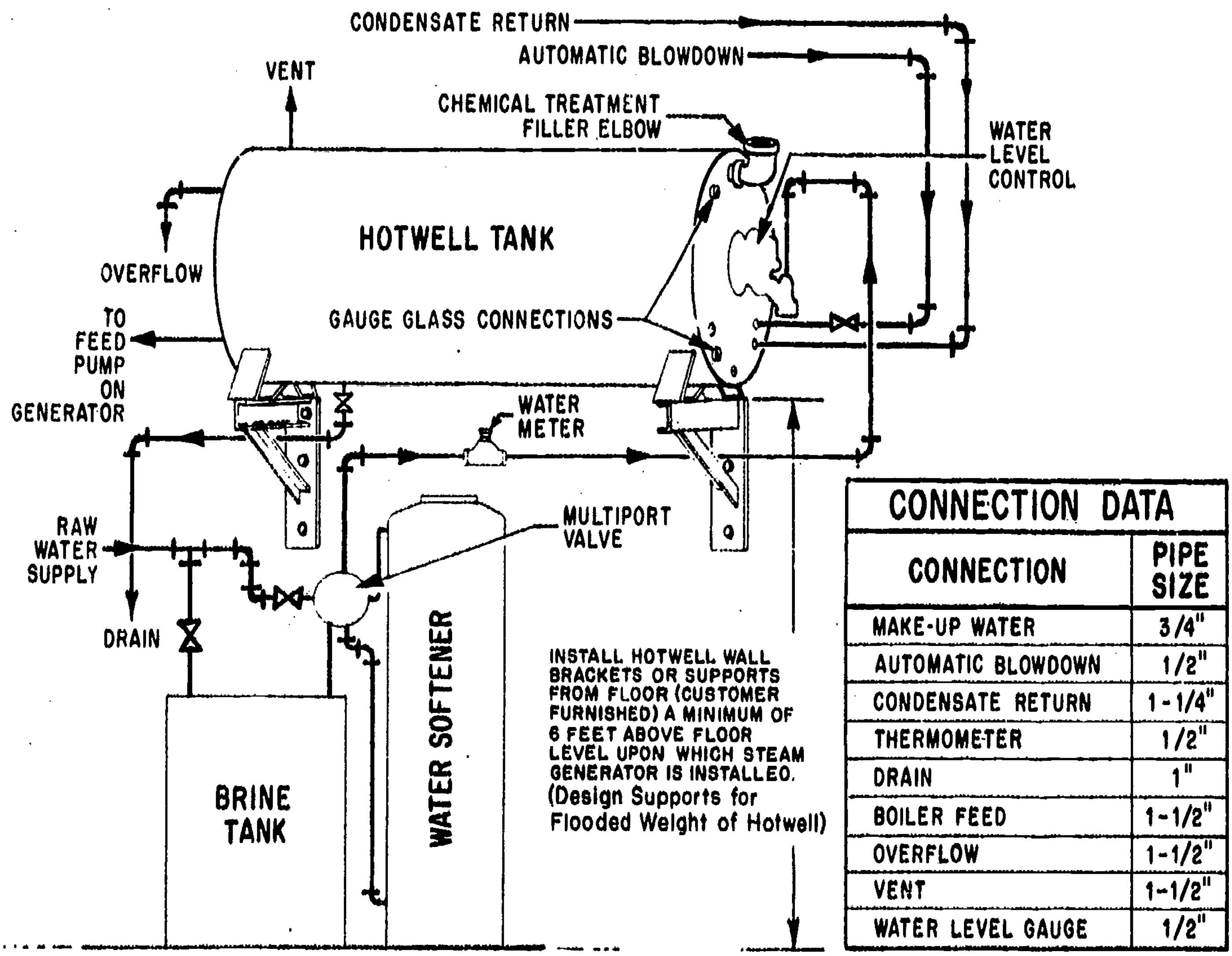
Venting Requirements

Install a stack adapter (supplied with the steam generator) directly on the heater cover stack outlet. Install a stack extension if desired, using 12-inch (minimum) flue pipe, and install a weather cap (supplied with the unit) at the top of the flue pipe.

If the unit is operated in an enclosed building, extend the flue pipe through the roof and install a weather cap. Where horizontal run is necessary, a minimum pitch of 15 degrees from the horizontal must be maintained. Increase the diameter of the flue pipe 2 inches for each 10 ft. of horizontal run. Also increase the diameter proportionately if more than one or a series of sharp bends is necessary.

Hotwell/Feed-Water Tank

A typical hotwell installation and connection data are shown in figure 18-13. The hotwell must be elevated on a suitable stand or bracket to allow a 60-inch gravity feed to the inlet of



CONNECTION DATA

CONNECTION	PIPE SIZE
MAKE-UP WATER	3/4"
AUTOMATIC BLOWDOWN	1/2"
CONDENSATE RETURN	1-1/4"
THERMOMETER	1/2"
DRAIN	1"
BOILER FEED	1-1/2"
OVERFLOW	1-1/2"
VENT	1-1/2"
WATER LEVEL GAUGE	1/2"

54.360

Figure 18-13.—A typical installation of horizontal hotwell and connection data.

the feed-water pump check-valve housing for hot-well temperatures up to 180° F. If higher hotwell temperatures are anticipated, a higher gravity feed is required to prevent vapor-locking of the feed-water pump. For hotwell temperatures of 180° to 200° F, a 72-inch gravity feed is necessary. Temperatures above 200° F require a gravity feed of 84 inches.

Feed-Water Connection

The feed-water connection is made by connecting a line between the feed pump connection on the hotwell and the feed-water intake valve, using 1-inch (minimum) pipe size.

Steam, Blow-Off, and Drain Connections

The steam header should be connected to the steam discharge valve. See that the header pipe size is not smaller than the steam discharge valve. It is recommended that a valve bleed line to the atmosphere be installed at the steam discharge. This will allow releasing steam to permit the steam generator to operate under full load condition when making certain adjustments.

Connect the pipe accumulator blowdown valve and coil drain valve to waste. These lines may be manifolded into a common line of not less than 1-inch pipe size.

Connect the pipe discharge from the steam safety valve to the atmosphere. You should provide a 1/4-inch (minimum) pipe size drain at the lowest point in the safety valve vent line piping.

The pipe outlet from the accumulator steam trap should be connected to the condensate return connection on the hotwell, using 3/4-inch pipe.

Automatic Blowdown Valve

To permit periodic checking of the automatic blowdown valve adjustment, a shut-off valve and a flow test valve should be installed as shown in figure 18-14. Pipe discharge from the shut-off valve to the automatic blowdown connection on the hotwell.

Electrical Connections

Make electrical connection to terminals in the electrical controls box. It is recommended that a disconnect switch be installed in the line adjacent to the steam generator to facilitate isolation of electrical components from the line in

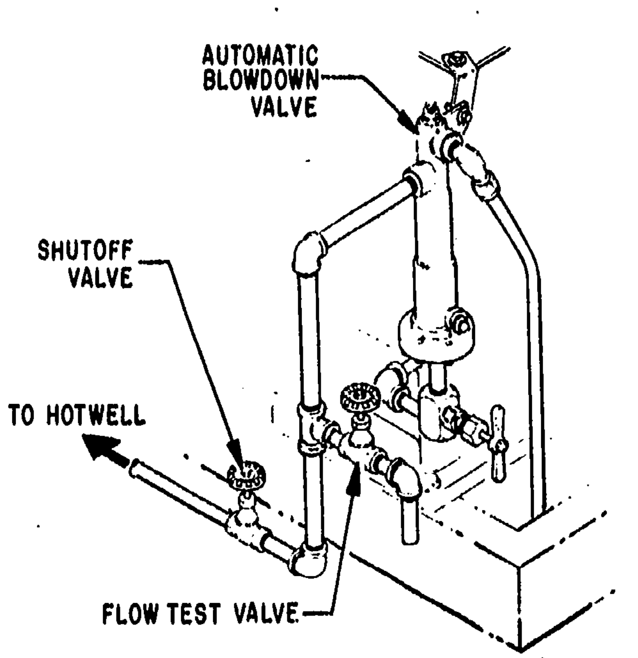


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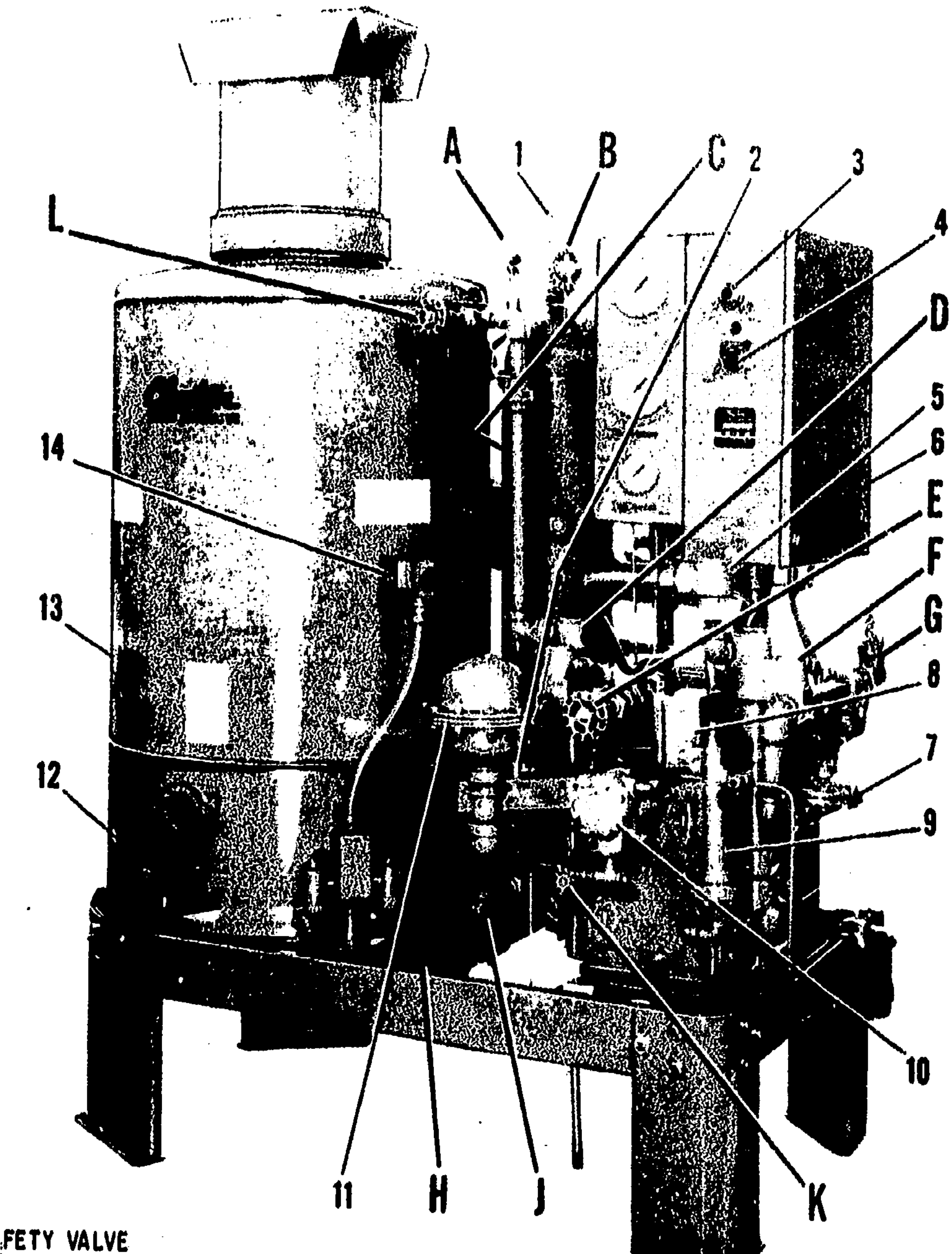
Figure 18-14. — Suggested automatic blowdown valve discharge piping.

case service is necessary. Start the motor momentarily to check rotation. Rotation should be clockwise as viewed from the front of the plant.

PREVENTIVE MAINTENANCE AND REPAIR

Like any piece of mechanical equipment, the steam generator will require proper maintenance and some repairs will be needed to maintain the efficiency and service it is designed to render. The following discussion covers some of the maintenance requirements and repair procedures applicable to the Clayton steam generator, model RO-33-PL. For detailed information on the maintenance and upkeep of this and other types of generator, consult the manufacturer's instruction manual.

Before proceeding, observe that figure 18-15 shows the operating controls and component parts as seen from the front of the generator, and that figure 18-16 shows the operating controls and component parts as viewed from the rear. The letters and numbers shown in parentheses in the sections that follow refer to those used to identify the name and location of operating controls and component parts in figures 18-15 and 18-16.



1. STEAM SAFETY VALVE
2. WATER PUMP RELIEF VALVE
3. START-STOP SWITCH
4. EMERGENCY RUN SWITCH
5. CHECK VALVE
6. ELECTRICAL CONTROLS BOX
7. INTAKE SURGE CHAMBER
8. WATER PUMP SOLENOID
9. AUTOMATIC BLOWDOWN VALVE
10. FUEL PUMP
11. WATER PUMP DISCHARGE SNUBBER
12. BURNER BASE
13. HEATING UNIT
14. THERMOSTAT SWITCH

A. SOOT BLOWER VALVE
B. STEAM DISCHARGE VALVE
C. ACCUMULATOR GAUGE GLASS
D. CIRCULATING PUMP HOUSING
E. CIRCULATING FEED VALVE
F. FEEDWATER PUMP HOUSING
G. FEEDWATER INTAKE VALVE
H. ACCUMULATOR BLOWDOWN VALVE
J. COIL DRAIN VALVE
K. BURNER CONTROL VALVE
L. COIL FEED VALVE

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Figure 18-15.—Operating controls and component identification of Clayton steam generator, model RO-33-PL—FRONT VIEW.

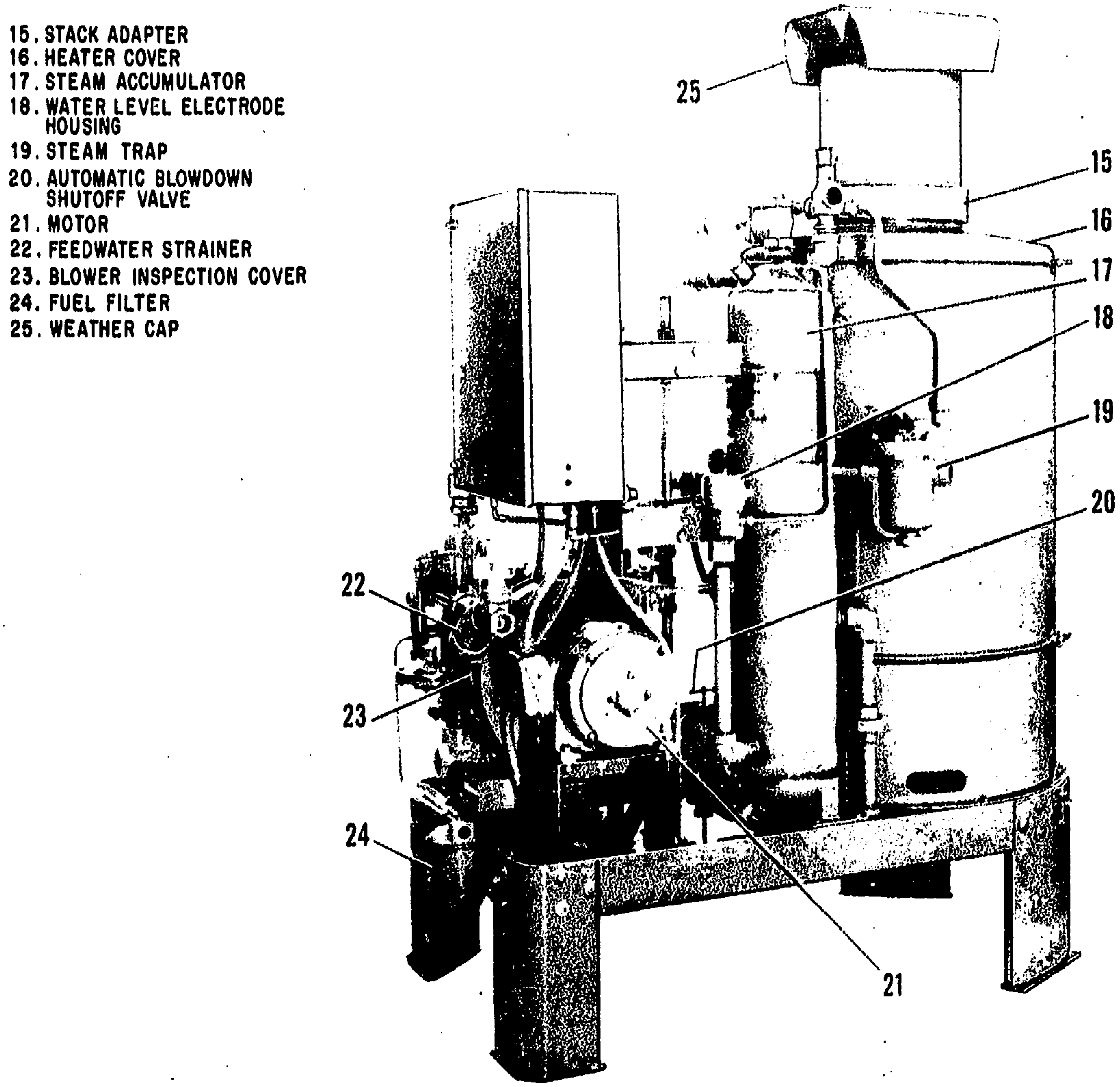

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Figure 18-16.—Operating controls and component identification of Clayton steam generator, model RO-33-PL—REAR VIEW.

Cleaning Blower

If dirt or lint is allowed to accumulate on the cupped sides of the blower rotor blades, shortage of air to the burner will cause reduced burner efficiency. The frequency of cleaning will depend on the amount of dirt or lint in the air at the particular installation. To clean, unscrew the wing nut and remove the blower inspection cover (23). Insert the curved end of the cleaning tool (see fig. 18-17) under the rotor blade and move the tool back and forth until the entire under surface of the blade is cleaned. Repeat this operation on all blades.

Thermostat Control Test

Check the operation of the thermostat control every 100 operating hours. Study the complete

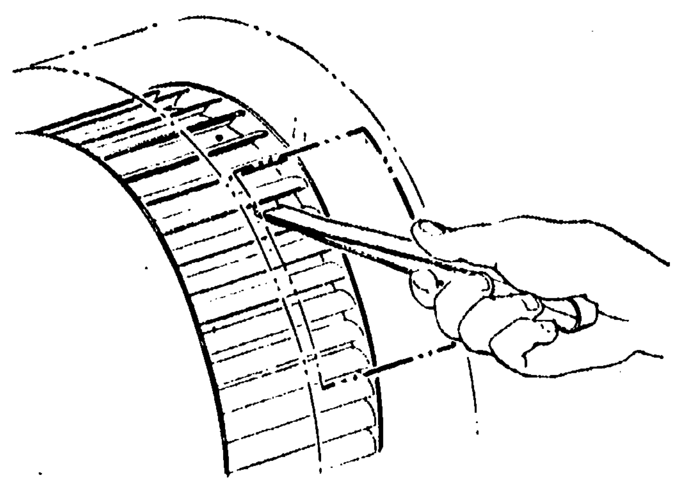

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Figure 18-17. — Using the blower rotor cleaning tool.

test procedure below and then follow the steps in rapid succession.

With the plant operating at normal pressure (burner on), close the feed-water intake valve (G) and circulating feed valve (E).

With the burner still on, open the coil drain valve (J) and accumulator blowdown valve (H). Now start a 60-second maximum time check. It should be remembered that the 60-second maximum timing of the burner shut-off starts at the INSTANT that the coil drain valve and accumulator blowdown valve are opened.

Progressively close the steam discharge valve (B) in such a manner that steam pressure will not rise to maximum but will be maintained about 5 to 10 psi below the steam pressure switch cut-out point. This will permit continuous burner operation without cut-off by the steam pressure switch. After the discharge valve is fully closed, do not reopen until the time check is complete.

If the thermostat is in correct adjustment, the burner will shut down within 60 seconds after the coil drain and accumulator blowdown valves (H and J) are opened.

CAUTION: If the burner fails to shut down within 60 seconds (maximum), shut off fire immediately and adjust the thermostat for proper control. The procedures for adjusting the thermostat switch and the thermostat ring channel are given later in this chapter.

After the burner shuts down, open the burner control valve. Close the coil drain and accumulator blowdown valves (H and J).

Open the feed-water intake valve (G) and the circulating feed valve (E). Allow the plant to fill with water, and prime the circulating pump if necessary.

To resume operation, start the burner when the plant is filled.

Check For Coil Restriction

When a water pump is noisy in operation the trouble is sometimes due to a restricted heating coil causing excessive feed pressure. In such cases the feed pressure should be checked for coil restriction. When checking for coil restriction, compare the reading on the feed pressure gage with that on the steam pressure gage. Normal feed pressure may vary slightly with each installation. It is advisable to carefully note the pressure immediately after the steam generator is installed so that an accurate check of coil restriction can be made for the particular unit. Always note feed pressure after the steam generator has operated for a while and thoroughly heated, and always at the same operating steam pressure. Steam pressure must be maintained at least 25 to 30 psi below the maximum, under steady load condition, to prevent burner modulation. To check feed pressure, open the valve to the feed pressure gage just enough to allow a steady reading on the gage. Coil restriction is indicated if feed pressure is 30 pounds or more above the normal feed pressure noted immediately after installation or when the coil was completely clean. For example, if it is noted that feed pressure was 250 psi at a given steam pressure when the unit was in new condition, remove scale from the heating coil when this pressure rises to 280 psi.

Blowdown Operation

To blowdown the system, follow this procedure:

With the plant operating at normal steam pressure, close the circulating feed valve (E) and open the coil drain valve (J). Start a time check.

After 30 seconds, shut off the burner and close the steam discharge valve (B).

NOTE: If the burner is shut down by the thermostat control during the time check, immediately open the burner control valve (K); then close the steam discharge valve.

Open the accumulator blowdown valve (H).

When the steam pressure drops to zero, close the coil drain valve (J) and the accumulator blowdown valve (H).

Open the circulating feed valve (E).

To resume operation, allow the plant to fill with water and start the burner in the normal manner. It may be necessary to reprime the circulating pump after the blowdown.

Priming Pumps

To prime the feed-water pump, open the sample valve on the side of the housing until air is expelled. If the pump fails to prime, loosen the intake valve cap two turns, to eliminate air; then retighten. Be careful when loosening this cap as it has the pressure of water from the hotwell against it.

Prime the circulating pump in a similar manner as for the feed-water pump. Check to be sure the circulating pump is primed by slowly closing the coil feed valve (L) and observing the feed pressure gage. If the pump is primed, feed pressure will rise when the valve is nearly closed. As a positive check, continue to close the valve until the pump relief valve (2) begins to discharge. The circulating pump is not fully primed if the relief valve cannot be made to discharge. Fully open the coil feed valve after the positive check is completed. In priming the pump, do not loosen the cap on the intake valve of the circulating pump, if any pressure is on the boiler. This cap is under the same pressure as the boiler.

Lubrication

If the electric motor is equipped with sealed bearings, the bearings are pre-lubricated for the life of the bearings. Motors equipped with oil-wick lubricated bearings should be given 1 teaspoon of good grade oil into reservoirs each 6 months. Too much oil can be just as harmful as not enough. Too much oil will allow seepage into the motor and will be evidenced by excessive oil around the motor shaft. If the motor is equipped with pressure grease fittings, remove the plug below the motor shaft every 6 months and force a light grade of grease into the port at the top until clean grease appears at the plug outlet. To prevent rupture of the grease seals, run the motor for 4 or 5 minutes before replacing the plug below the motor shaft.

Every year (more often under severe operation), drain and refill the water pump crankcase with a good grade of SAE 20 motor oil (about 5 quarts required). With the pump running, oil should show at least halfway in the sight gage.

Water Pump Check Valves

When the water pump's check valves are not operating properly, it may be necessary to inspect and clean the valves. The valves should also be inspected and cleaned when removing scale from a restricted heating coil.

In the following discussion on check valves, refer to the drawing of a water pump in figure 18-18 as we go along. This illustration has been labeled to show the name and location of different parts of the water pump and the numbers shown in parentheses in the test refer to those shown in figure 18-18.

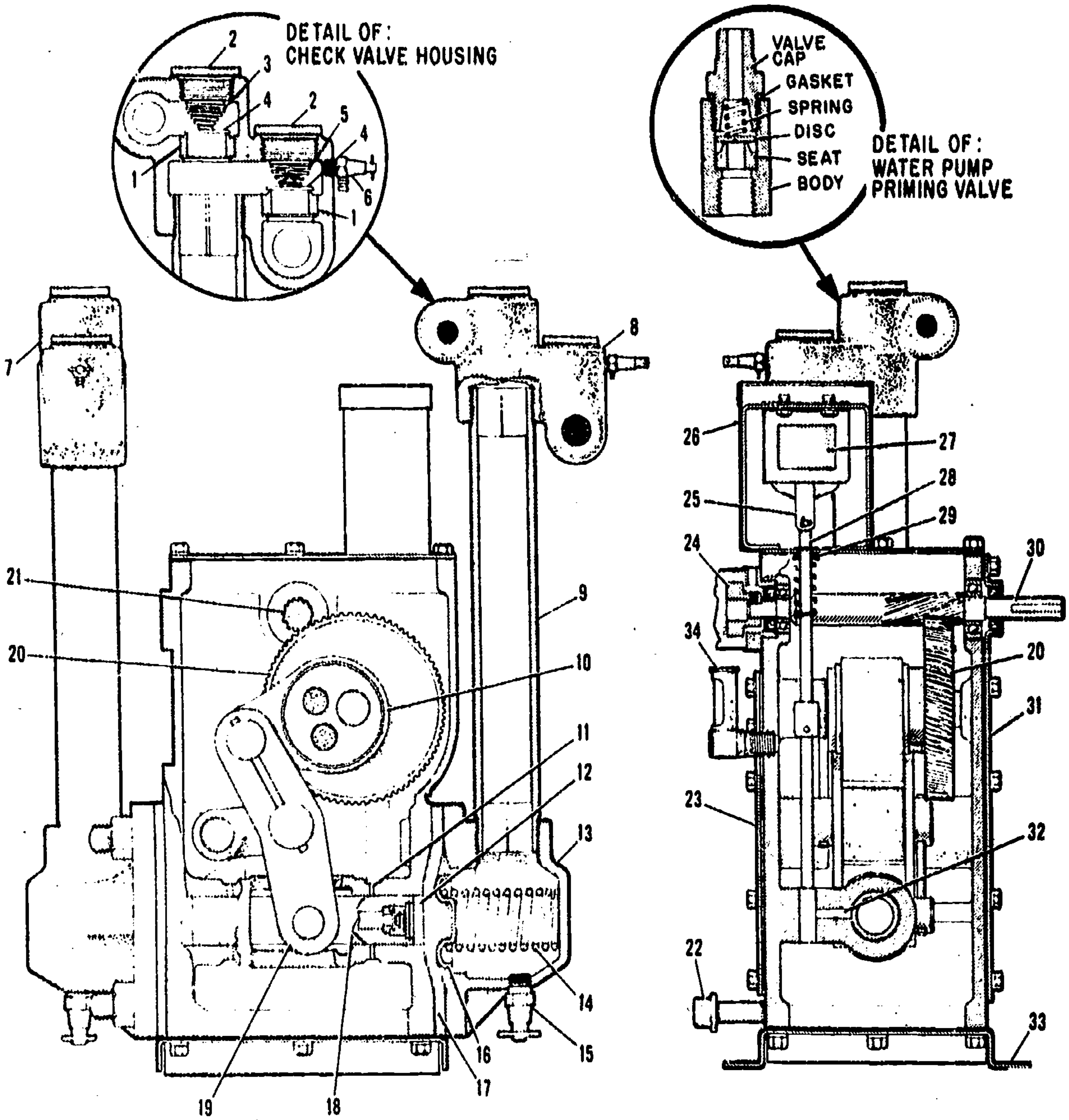
When inspecting the check valves, unscrew the valve caps (2) from the housings (7 and 8) and disassemble the disks (4) from the caps. Remove scale and pits from the disks by rubbing them in a "figure 8" motion on a piece of fine sandpaper (wet-or-dry No. 400 or finer) placed on plate glass. The disks must be perfectly smooth and flat for proper water pump operation.

Inspect the springs (3 and 5) for distortion and free length. The free length of discharge springs (3) should be 1-1/32 inch; the free length of intake springs (4) should be 25/32 inch. Replace any broken or distorted springs.

When reassembling, make sure you first assemble the spring to the disk by placing the finger inside the spring at the center and pressing the small end of the spring over the button on the disk; then attach the spring to the valve cap. This will prevent unnecessary distortion and possible deformation of the springs. Remove and process the check valves one at a time to avoid interchanging parts.

Inspect the valve seats (1) to determine if they are scored or damaged. Seat faces must be narrow and perfectly flat. Replace damaged seats, following instructions given in the section below.

Scale may be removed from the inside of check valve housings by filling the housings and pump columns with a solution of two parts water and one part of a Navy-approved scale-removing acid. Scale on springs and disks may be removed by immersing in the same solution. After the scale has been dissolved, thoroughly flush the parts with water. Open the drain cocks (15) to flush the pump columns.



1. Valve Seat
2. Valve Cap
3. Discharge Spring
4. Valve Disc
5. Intake Spring
6. Bleeder Cock
7. Circulating Housing
8. Feedwater Housing
9. Pipe Column
10. Connecting Link
11. Oil Port
12. Hydraulic Chamber
13. Pump Head
14. Spring
15. Drain Cock
16. Diaphragm Cup
17. Diaphragm
18. Piston
19. Rocker Arm
20. Main Gear
21. Pinion Gear
22. Drain Cap
23. Front Cover
24. Fuel Pump Coupling
25. Solenoid Armature
26. Solenoid Housing
27. Solenoid
28. Bypass Rod
29. Packing
30. Drive Shaft
31. Rear Cover
32. Bypass Port
33. Base
34. Oil Level Gauge

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Figure 18-18.—Water pump.

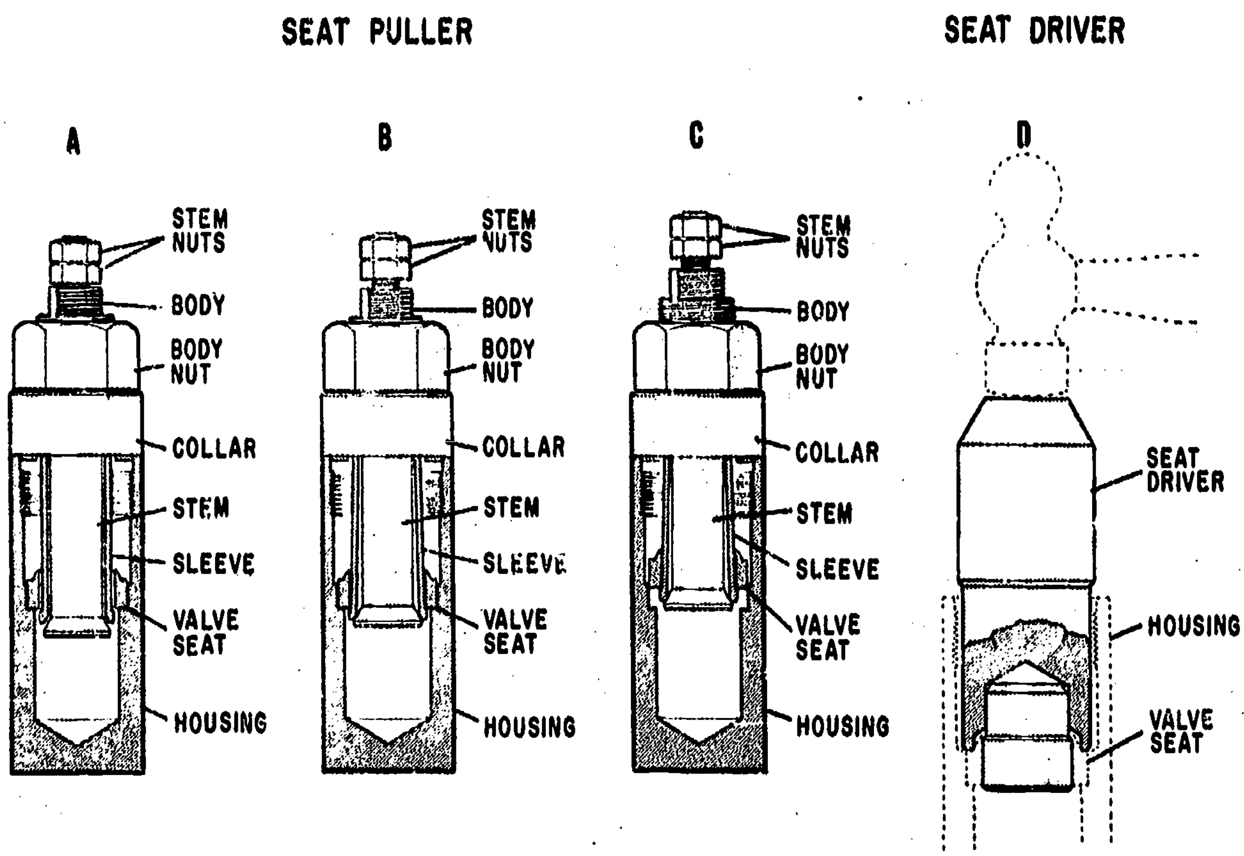

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Figure 18-19. — Use of special seat puller and seat driver.

Replacing Water Pump Seats

To replace valve seats in the water pump, it will be necessary to use a special seat puller and a special seat driving tool. Using these tools, the procedure is as follows:

Adjust the seat puller so that the wedge at the lower part of the stem is free of the sleeve and unscrew the body nut sufficiently to allow the shoulder on the sleeve to extend below the valve seat when the puller is inserted into the check valve housing (see view A, fig. 18-19).

Insert the puller in the check valve housing and turn the stem counterclockwise with the stem nuts until the shoulder on the sleeve is securely wedged below the bottom of the valve seat (see view B, fig. 18-19).

Hold the body with the wrench and turn the body nut clockwise until the valve seat is free of the check valve housing (see view C, fig. 18-19). Remove the seat puller and turn the stem clockwise to free the seat.

Drive in the new seat with the seat driving tool (see view D, fig. 18-19) using care to avoid damaging the seat face.

Water Pump Relief Valve

The water pump's relief valve should be adjusted to open at about 500 psi feed pressure but remain drip-tight during operation. Leakage from this valve will result in insufficient water to the heating unit and cause overheating.

You will find that under certain conditions, when starting the unit, feed pressure may temporarily rise sufficiently to cause the relief valve to release a small amount of water. Feed pressure will return to normal, however, after th unit heats and the system becomes stabilized.

A drawing of a pump relief valve is shown in figure 18-20. In the following instructions on the adjustment and repair of the relief valve, the numbers in parentheses refer to those used in figure 18-20.

To adjust the relief valve, the procedure is as follows: Start the plant without the burner in operation and slowly close the coil feed valve

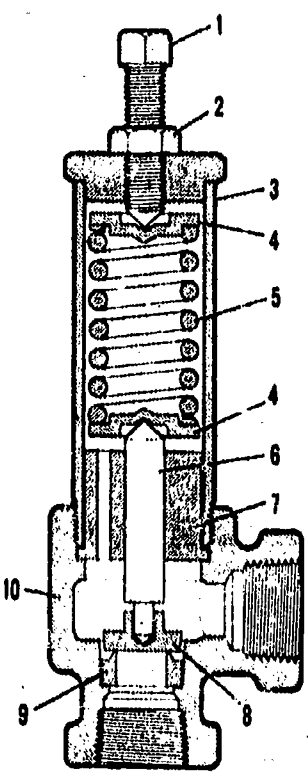

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Figure 18-20. — Pump relief valve.

(see L, fig. 18-15) until the relief valve just begins to discharge; check the pressure on the feed pressure gage at that point.

To raise the pressure adjustment, turn the adjusting screw (1) clockwise; to lower the pressure adjustment, turn the screw counterclockwise. Secure the adjusting screw with the locknut (2) after the adjustment.

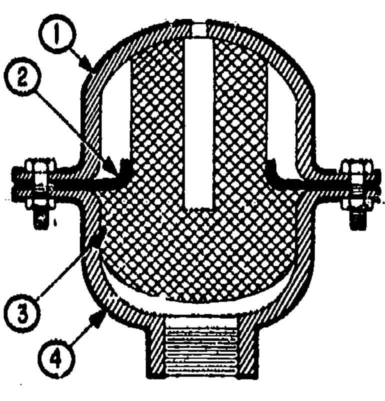

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Figure 18-21. — Water pump discharge snubber.

Fully open the coil feed valve. Inspect the valve for leakage during normal operation.

To repair the relief valve the following procedure applies:

Loosen the adjusting screw (1) and unscrew the housing (3) from the body (10). Inspect the disk (8) and seat (9) for scored or damaged condition. Replace the seat if damaged.

If the disk is scored, it may be resurfaced by rubbing it on a piece of fine sandpaper (wet-or-dry No. 400 or finer) placed on a perfectly flat surface.

Reassemble the valve, making sure the spring washers (4) are not cocked in the housing.

Water Pump Discharge Snubber

The water pump discharge snubber (see fig. 18-21) is nonadjustable. If replacement of the rubber insert is necessary, the old inset must be cut away from the retainer. To facilitate assembly, lubricate the new insert with glycerine (do not use oil) to allow it to be pushed into the retainer and bottom housing.

Ring Thermostat Control

To keep the generator's ring thermostat control (fig. 18-22) in peak operating condition, it may be necessary at times to adjust the thermostat switch and the thermostat ring channel. In making these adjustments, follow the procedures below. The numbers in parentheses in the subsections below refer to those used in figure 18-22.

THERMOSTAT SWITCH ADJUSTMENT. — The plant must be operated long enough to be thoroughly heated before making the thermostat switch adjustment.

Remove the cover from the themostat switch (22) to expose the adjusting nut (18).

With the plant operating, adjust the steam discharge so that steam pressure will be maintained just below the steam pressure switch cut-out point. This will provide maximum steam temperature and prevent burner cut-off by the steam pressure switch during adjustment.

Slowly turn the thermostat adjusting nut (18) out until it actuates the thermostat switch to cut-off the burner; then turn the nut back in about 3/4 turn. This should allow the burner to again start.

1. LOCKNUT
2. WASHER
3. GUIDE PLATE
4. HEX NUT
5. WASHER
6. GASKET
7. ANCHOR STUD
8. CHANNEL ADJUSTING SCREW
9. LOCKNUT
10. WASHER
11. GUIDE NUT
12. PRE-LOAD BUTTON
13. TIE-STRAP
14. LOCKWASHER
15. CAPSCREW
16. GASKET
17. ADJUSTING STUD
18. ADJUSTING NUT
19. SWITCH MOUNTING BRACKET
20. WASHER
21. SPRING
22. THERMOSTAT SWITCH
23. THERMOSTAT RING CHANNEL
24. OUTER SHELL
25. RING THERMOSTAT TUBE

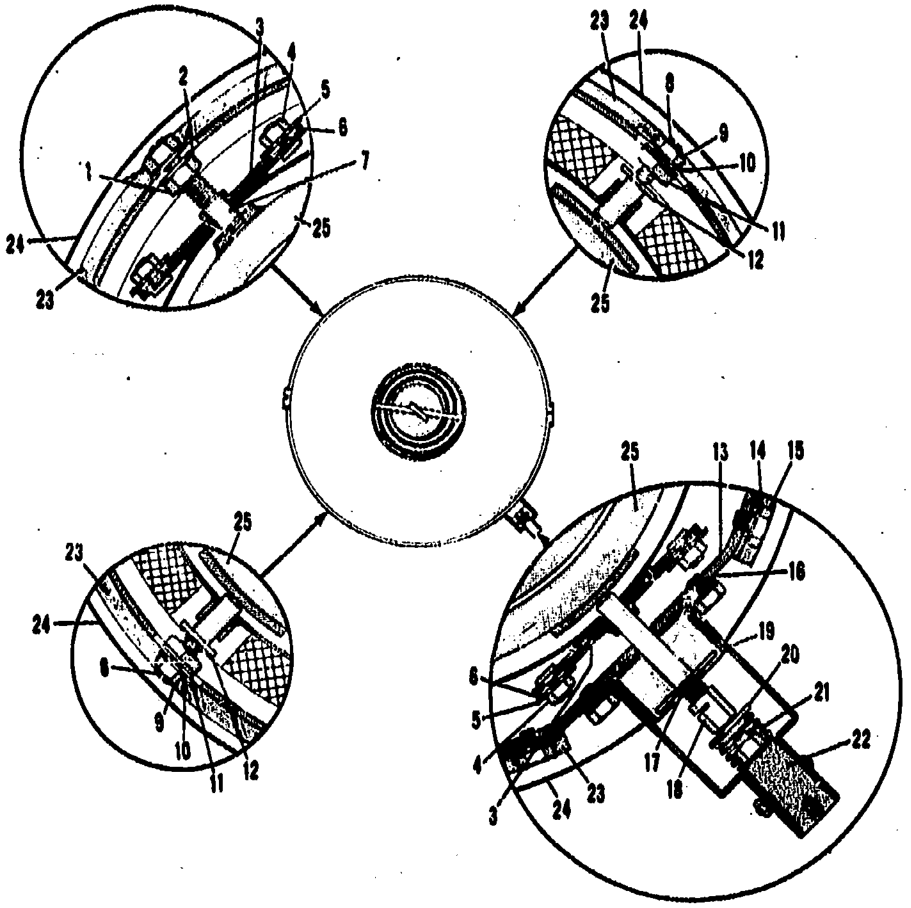

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Figure 18-22. — Ring thermostat control.

Test the thermostat as instructed earlier in the section entitled "Thermostat Control Test." A slight readjustment of the thermostat adjusting nut may be necessary to obtain correct safety shutdown of the burner.

THERMOSTAT RING CHANNEL ADJUSTMENT. — Adjustment of the thermostat ring channel (23) must be made when replacing the heating coil, or if the original assembly has been disturbed in any way. A careful check of the adjustment must also be made if the thermostat switch cannot be adjusted without erratic response.

In adjusting the thermostat ring channel, be sure the guide plates (3) are tightly secured to the flanges at the front and rear of the coil. Also be sure the tie-strap (13) is tightly secured to the ring channel (23).

Loosen the locknuts (1) and securely tighten the anchor stud (7) into the boss at the rear of the ring thermostat tube (25).

With the channel adjusting screws (8) loosened so that the channel (23) is free to move, adjust the locknuts (1) at the rear of the channel to a point where the clearance between the channel and the coil insulation is approximately equal at the front and rear. Do not completely tighten the locknuts.

Adjust the channel adjusting screws (8) to a point where the clearance between the channel and the coil insulation is approximately equal at the sides. Take up all lateral "play" against the pre-load buttons (12) without excessive pressure against the buttons.

Check the alignment of the adjusting stud holes in the tie-strap (13) and the front guide plate (3). It may be necessary to rotate the ring channel to bring these openings into alignment. After alignment is properly made, tightly secure the locknuts (1) at the rear of the channel.

Again adjust the channel adjusting screws (8) so that they center the ring channel in relation to the coil insulation and bear against the pre-load buttons just enough to take up "play." Then turn each adjusting screw in one-half to one turn additionally to create a proper pre-load on the channel; then secure with locknuts (9). Adjusting screws should be positioned approximately at the center of the pre-load buttons.

Check the clearance between the ring channel and the coil insulation. A clearance of at least 1/16 inch should be allowed at all points around the insulation. Also be sure that clearance (1/16 inch minimum) is allowed between the ring channel and the outer shell (24) when the outer shell is secured in the burner base.

Install the adjusting stud (17), adjusting nut (18), bracket (19), washer (20), spring (21), and switch (22). Make the thermostat switch adjustment as instructed above.

Automatic Damper

The automatic damper should be kept in proper adjustment to ensure a proper supply of air to the burner.

When the air supply is to be adjusted for HIGH FIRE burner operation, the following procedure applies: With the plant operating, regulate steam discharge to keep the steam pressure at least 25 psi below maximum to ensure full

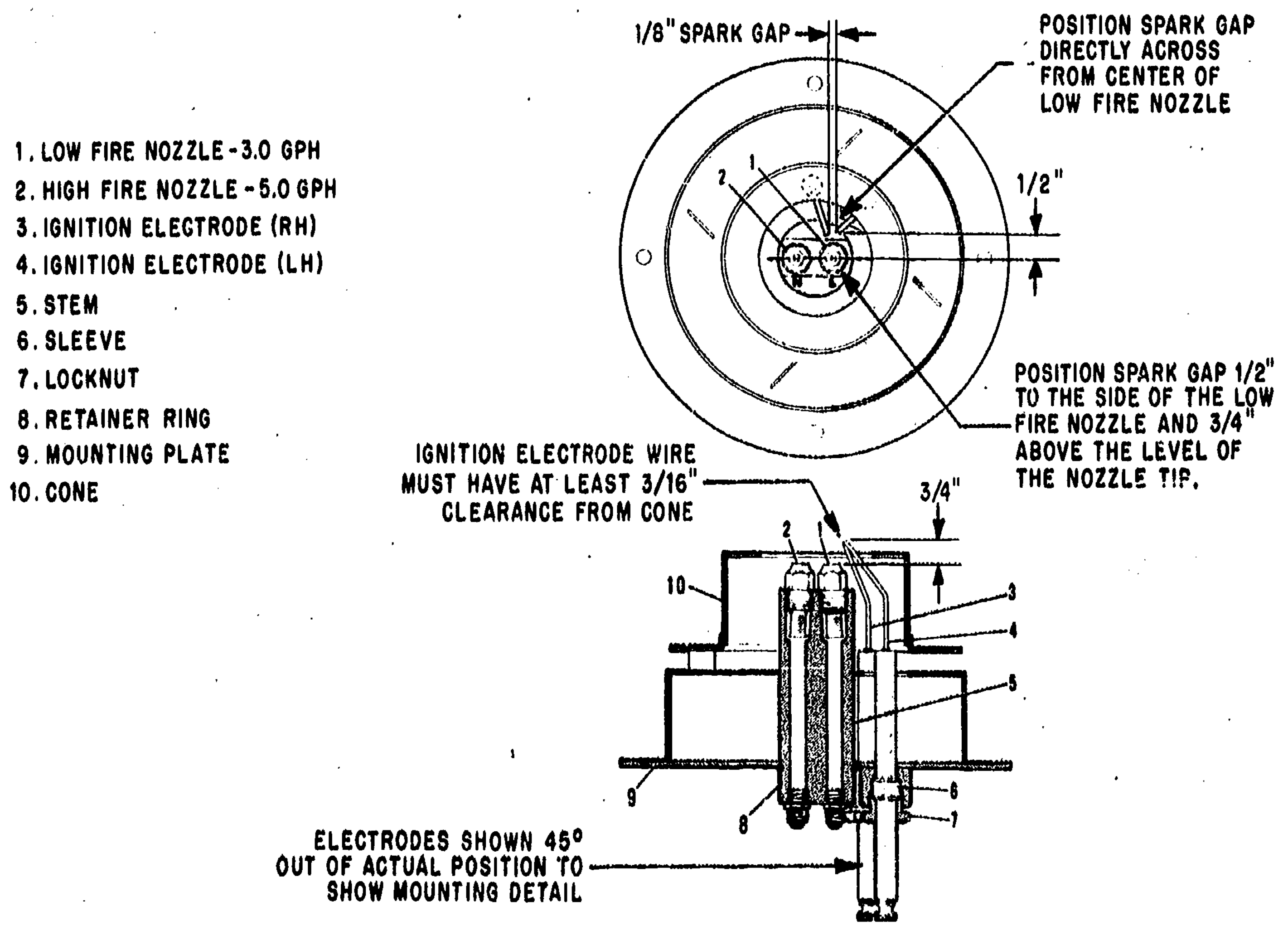

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Figure 18-23.—Burner manifold.

burner operation. Loosen the wing nut on the "high fire" adjusting screw and turn the adjusting screw clockwise until smoke is noticed at the stack outlet; then turn the screw counterclockwise until smoke just disappears. Most efficient burner operation is accomplished by adjusting the air just to the point of smoke elimination.

When the air supply is to be adjusted for LOW FIRE burner operation, operate the plant at near maximum steam pressure (between 5 and 10 psi below maximum). The low fire adjustment is made in the same manner as the high fire adjustment except that the "low fire" adjusting screw is turned counterclockwise until smoke appears at the stack outlet; then turned clockwise until smoke just disappears.

Burner Manifold

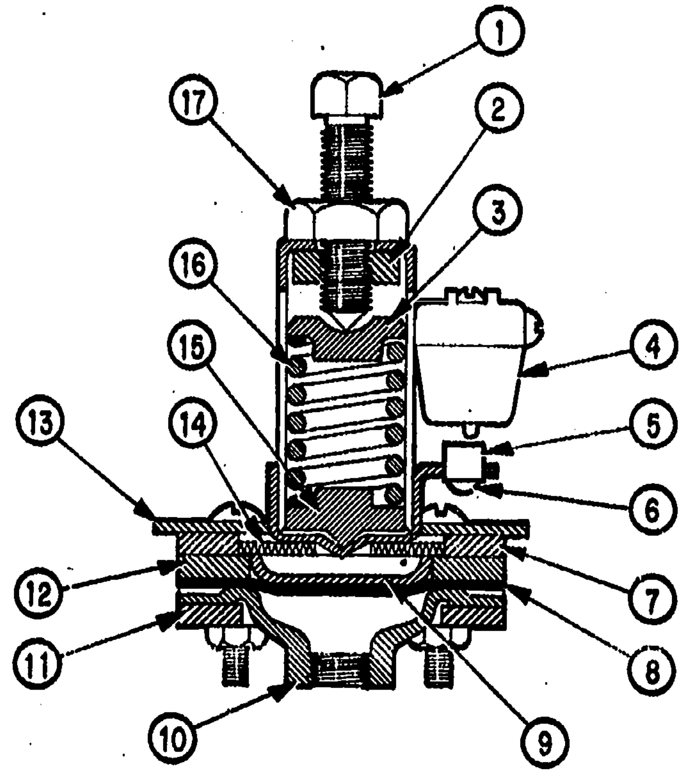
The burner manifold (fig. 18-23) will require cleaning and adjusting at times to keep it in efficient operating condition. The procedure for cleaning and adjusting the burner manifold is as follows:

Disconnect the fuel lines and remove the cables from the burner manifold. Unscrew the nuts which attach the manifold to the burner volute and remove the manifold. Scrape carbon deposits from the manifold and ignition electrodes.

Unscrew the burner nozzles from the stem. Unscrew the strainer from the nozzle and remove the screw. Blow parts out with a compressed air jet if available. Be sure all dirt and grit are removed.

CAUTION: In cleaning, do not use a sharp instrument, which can scratch or disfigure the tip orifice or slots in the distributor. A slight scratch on these parts can seriously impair nozzle operation.

Adjust ignition electrodes to conform with dimensions given in figure 18-23. The gap must be positioned as accurately as possible so that it is at the immediate edge of the nozzle spray. Due to slight differences in individual nozzle spray angles, it may be necessary to position the gap somewhat nearer or farther from the nozzle than indicated. If points are placed too far into the spray, impingement of fuel on the electrodes will cause fuel drip from the burner. If the gap is too far away, erratic ignition or ignition failure will result. The electrodes may be raised, lowered, or rotated by loosening the locknuts attaching them to the mounting plate.



LEGEND:

1. ADJUSTING SCREW
2. NUT PLATE
3. SPRING WASHER
4. SWITCH
5. LEAF SPRING
6. SPRING GUIDE
7. GUIDE RING
8. DIAPHRAGM
9. DIAPHRAGM WASHER
10. BASE
11. RING
12. GUIDE RING
13. COVER
14. WASHER
15. PIVOT WASHER
16. SPRING
17. LOCKNUT

54.369

Figure 18-24. — Fuel pressure switch.

Make sure you exercise care when bending and adjusting the electrodes to avoid cracking the insulators. The insulators may develop an invisible short due to such a fracture, resulting in ignition failure.

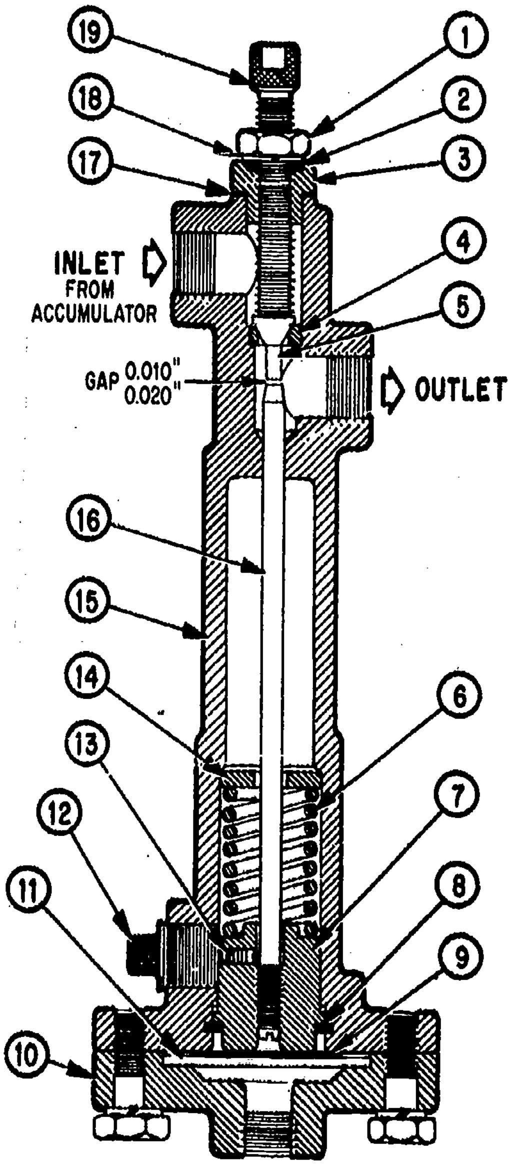
Fuel Pressure Regulator

It is very important that the fuel pressure to the burner be properly maintained. Excessive fuel pressure will cause the burner to smoke and result in sooting of the heating coil. However, if fuel pressure is too low, the plant will be slow in coming up to pressure and will not maintain adequate steam pressure during periods of maximum steam demand. Normal fuel pressure will range between 140 to 160 psi, depending upon the type and gravity of fuel used. Avoid raising fuel pressure to a point where the generator is overfired, causing thermostat interruption. To adjust fuel pressure, operate the burner at full fire and remove the cap nut from the lower right-hand side of the fuel pump. Insert a screwdriver and turn the adjusting screw clockwise to increase pressure; counterclockwise to decrease pressure.

Fuel Pressure Switch

Figure 18-24 shows a drawing of a fuel pressure switch. If it becomes necessary to adjust the switch, follow the procedure below.

Adjust the switch to close the light and fuel indicator pilot when fuel pressure rises to about 70 psi by turning the adjusting screw (see (1), fig. 18-24) clockwise to increase, or counterclockwise to decrease pressure at which the switch will close. This will allow sufficient pressure to induce proper atomization when fuel



LEGEND:
1. NUT, LOCK, 3/8"-24
2. SEAL
3. CAP, VALVE
4. SEAT, VALVE
5. STEM
6. SPRING
7. WASHER, DIAPHRAGM
8. RING, LOCK
9. DISC, BUFFER
10. BASE
11. DIAPHRAGM
12. PLUG, PIPE, 3/8"
13. SCREW, SET, 10-32 x 1/4"
14. WASHER, SPRING
15. BODY
16. ACTUATOR
17. GASKET
18. WASHER
19. SCREW, ADJUSTING

54.370

Figure 18-25. —Automatic blowdown valve.

Table 18-1.—Troubleshooting Chart for Clayton Steam Generator, Model RO-33-PL

WATER SYSTEM.

Trouble	Possible Cause	Remedy
FEEDWATER PUMP FAILING TO MAINTAIN PROPER WATER LEVEL IN ACCUMULATOR GAGE GLASS	Accumulator blowdown valve open or leaking.	Inspect accumulator blowdown valve.
	Feedwater pump not primed.	Prime pump.
	Insufficient water to feedwater pump.	Check water supply to pump. Be sure intake valve is open.
	Feedwater strainer clogged.	Clean strainer.
	Feedwater pump check-valves not operating properly.	Clean and inspect check-valves.
	Water pump solenoid not releasing.	Remove water level electrodes and clean off rust and dirt.
		Check water pump solenoid armature and linkage for binding.
CIRCULATING PUMP FAILING TO MAINTAIN PROPER FEED VOLUME TO HEATING COIL, CAUSING THERMOSTAT INTERRUPTION.	Low oil level in water pump causing reduced pump capacity.	Be sure oil is maintained at proper level.
	Priming valve not operating properly.	Clean and inspect priming valve.
	Circulating pump check-valves not operating properly.	Clean and inspect check-valves.
	Vapor-lock of circulating pump due to abrupt steam demand causing low pressure in accumulator.	On installations where there are sudden heavy steam demands, a back pressure valve should be installed to retain a normal steam pressure in the accumulator during these periods.
	Circulating pump not primed.	Prime circulating pump.
TOO MUCH WATER. (Unit operating with high water level in gage glass.)	Water pump solenoid not operating.	Check for burned out solenoid coil or open circuit to solenoid.
		Remove and clean water level electrodes. Corrosion on electrodes may cause insulating effect and prevent operation of solenoid.

54.371.1

Table 18-1.—Troubleshooting Chart for Clayton Steam Generator, Model RO-33-PL—Continued

WATER SYSTEM.—Continued.

Trouble	Possible Cause	Remedy
TOO MUCH WATER—Continued.	Water pump solenoid not operating.	Check for defective water level relay.
	Steam trap plugged.	Remove and clean steam trap.
NOISY WATER PUMP OPERATION.	Flexible coupling loose between motor and pump.	Tighten setscrews in flexible coupling.
	Pump intake surge chamber fouled.	Check and clean intake surge chamber.
	Restricted heating coil causing excessive feed pressure.	Check feed pressure for coil restriction.
WATER PUMP CYCLES RAPIDLY.	Leads to water level electrodes reversed.	Check wiring to electrodes (see wiring diagram).

FUEL SYSTEM.

Trouble	Possible Cause	Remedy
LOW OR NO FUEL PRES-URE. Caution: Stop plant immediately to avoid damage to the fuel pump.	Fuel supply exhausted or supply lines restricted.	Check fuel supply. Be sure all valves in supply line are open.
	Fuel bypassing through burner control valve.	Burner control valve must be fully closed for maximum fuel pressure.
	Fuel pressure not adjusted properly.	Adjust fuel pressure.
	Air leak in supply line causing loss of prime.	Suction line must be airtight and all air pockets eliminated.
	Fuel pump failure.	Replace fuel pump.
BURNER FAILS TO IGNITE.	Faulty ignition.	Check and adjust ignition electrodes.
		Check ignition transformer and cable.
		Check for low voltage condition which may cause weak spark from transformer.
	Safety switch in combustion control locked out.	Actuate reset on control. Also check for continuity of circuit between combustion control and flame detector (under burner manifold).

54.371.2

Table 18-1.—Troubleshooting Chart for Clayton Steam Generator, Model RO-33-PL—Continued

FUEL SYSTEM.—Continued.

Trouble	Possible Cause	Remedy
BURNER FAILS TO IGNITE—Continued.	Fuel pressure switch failure.	Check and adjust fuel pressure switch.
	Burner nozzles not replaced in burner.	Be sure to replace nozzles after cleaning burner manifold.
	Insufficient fuel pressure.	Check causes and remedies under "Low or No Fuel Pressure."
	Oil valve failing to open.	Check for burned out solenoid.
PARTIAL OR IMPROPER BURNER OPERATION CAUSING LOW STEAM PRESSURE AT NORMAL LOAD.	Low fuel pressure.	Check causes and remedies under "Low or No Fuel Pressure."
BURNER SHUTS OFF BEFORE MAXIMUM STEAM PRESSURE IS REACHED.	Thermostat control interruption due to low water condition.	Correct cause of low water condition immediately. Test thermostat for proper control.
SMOKE FROM FLUE OUTLET. To prevent sooting of the heating coil and burner, this condition must be corrected immediately.	Improper air supply to burner.	Check air adjustment.
	Fuel pressure not adjusted properly.	Adjust fuel pressure.
	Carboned, loose, or worn burner nozzles.	Clean and tighten burner nozzles. Replace if worn.
	Heating coil sooted.	Remove soot from heating coil.
	Dirt or sludge in fuel oil or wrong grade of fuel used.	Be sure fuel is clean and of the proper grade.
FLUTTERING BURNER SHUT-OFF DURING AUTOMATIC OPERATION.	Oil valve not seating properly.	Check and clean solenoid valve.
OIL DRIP FROM BURNER.	Oil valve not seating properly.	Check and clean solenoid valve.
	Loose burner nozzles.	Tighten nozzles.
	Carbon on burner nozzles causing deflection of oil spray.	Remove and clean nozzles.

54.371.3

Table 18-1.—Troubleshooting Chart for Clayton Steam Generator, Model RO-33-PL—Continued

FUEL SYSTEM.—Continued.

Trouble	Possible Cause	Remedy
DEAD OR FLUTTERING FIRE.	Heating coil sooted.	Remove soot.
	Improper air adjustment.	Check air adjustment.

ELECTRICAL SYSTEM.

Trouble	Possible Cause	Remedy
MOTOR FAILS TO START, OR STOPS DURING OPERATION.	Power failure or tripped circuit breaker.	Check powerlines. Reset circuit breaker.
	Safety shutdown caused by overload relays.	Wait 2 or 3 minutes for overloads to cool; then press reset on magnetic controller and restart unit. Check for cause of overload.
MOTOR NOISY OR RUNNING HOT.	Motor running single phase.	Check for blown fuse or tripped circuit breaker in feeder lines.
MAGNETIC CONTROLLER FAILS TO CONTACT.	Operating coil failure.	Replace coil.

54.371.4

is admitted to the burner. Secure the adjusting screw with the locknut after adjustment.

Steam Pressure Switch

The steam pressure switch (SPS) can be adjusted to open and stop the burner at any desired maximum pressure between 65 and 195 psi. The switch will close and restart the burner when steam pressure drops about 8 psi below that point. To adjust, turn the large slotted screw at the top of the switch until the dial pointer on the switch is opposite the maximum pressure desired. The dial is approximate and final adjustment should be made, using the steam pressure gage as a criterion. If the steam pressure switch setting is changed, the modulating pressure switch should also be readjusted accordingly.

Modulating Pressure Switch

The modulating pressure switch (MPS) is normally adjusted to modulate the burner to "low fire" operation when steam pressure reaches 10 psi below maximum and return the burner to "high fire" operation when steam pressure drops about 8 psi below that point. This adjustment can be raised or lowered in relation to maximum steam pressure, but should never be set closer than 5 psi below the steam pressure switch cutout point. If it is set too close to the maximum steam pressure, operation will be unstable and there will be a tendency to "over-ride" during an abrupt drop in steam load. If set too low, steam pressure will not be maintained at high level duing heavy loads. The recommended setting of 10 psi below the maximum will, in most cases, provide both stable operation and relatively stable steam pressure during fluctuating demand. To adjust, turn the large slotted screw at the top of the switch until the dial pointer on the switch is opposite the pressure desired. As with the steam pressure switch, the dial setting is approximate and the steam pressure gage should be used for final adjustment.

Automatic Blowdown Valve

The automatic blowdown valve is operated by oil pressure from the water pump. If the blowdown valve diaphragm gets ruptured, the trouble will likely be indicated by the appearance of oil in the waste discharge. It is important that a ruptured diaphragm be replaced immediately to prevent the loss of oil from the pump crankcase. Figure 18-25 shows a drawing of a blowdown valve and its various parts. In this discussion on the blowdown valve, note that the numbers in parentheses refer to those used in figure 18-25.

As a preventive maintenance measure, it is recommended that the blowdown valve diaphragm be replaced whenever it is necessary to replace the water pump diaphragms. Since wear may in time affect the operation of the blowdown valve, it is also recommended that the valve be disassembled each time that the diaphragm is replaced and internal valve adjustments checked in accordance with the following instructions:

Disconnect the tubing and bracket from the blowdown valve. Unscrew the blowdown valve from the water pump. Disassemble the base (14) from the body (8) and remove the diaphragm (13) and the buffer disks (15) from the body.

Loosen the locknut (2) and turn the adjusting screw (1) in until it holds the valve stem (6) firmly against the valve seat (5).

Using a feeler gage through the outlet port, check the gap between the valve stem (6) and the actuator (7). The gap should be 0.010 inch (minimum) to 0.020 inch (maximum).

If adjustment is necessary, remove the pipe plug (16) and loosen the setscrew (17). Insert a screwdriver into the slot in the bottom of the actuator (7) and adjust the actuator for proper gap. Secure the actuator with a setscrew when proper adjustment is made.

Assemble the two buffer disks (15), diaphragm (13) and base (14) to the body (8) and secure with capscrews. Recheck to determine if the gap established earlier still exists.

Screw the blowdown valve into position into the water pump and secure the bracket with capscrews and hex nuts. Attach the tubing and adjust the valve for correct capacity, as specified in the manufacturer's instruction manual.

TROUBLESHOOTING CHARTS

A troubleshooting chart for the Clayton steam generator, model RO-33-PL, is shown in table 18-1. This chart will be useful to you as a guide in locating and correcting troubles in that particular make and model of generator. You will probably find similar charts in the instruction manuals provided by the manufacturers of other makes of steam generators. Make sure you are familiar with the manufacturer's manual for the generator used at your activity, and follow the procedures prescribed therein for the maintenance and repair of the equipment.

CHAPTER 19

REFRIGERATION

In civilian life, refrigerators and iceboxes are used to keep food from spoiling. In the Navy, where very large quantities of food must be stored, refrigeration systems for food storage warehouses are required. Refrigerated spaces are also used to store various items other than food. For instance, some medicines require refrigeration to prevent spoiling. Penicillin, which is used to fight infections, will become ineffective in a short time unless kept in a cool place. And blood, which often is needed to save lives, must be kept in refrigerated storage, or else it, too, will become useless. From these examples you can easily see the importance of refrigeration in military, as well as civilian, life.

The installation, adjustment, and repair of refrigeration equipment are primary responsibilities of the Utilitiesman's rating. To perform these and the related duties required of a refrigeration mechanic you will need to understand the principles and theory of refrigeration. The time and effort that you spend in learning these basics will be amply rewarded by your increased efficiency in performing your refrigeration duties.

REFRIGERATION DEFINED

Refrigeration is a general term used to describe the process of removing heat from an area or a substance and is usually applied to an artificial means of lowering the temperature such as the use of ice or mechanical refrigeration.

Mechanical refrigeration may be defined as a mechanical system or apparatus so designed and constructed that, through its function, heat is transferred from one substance to another.

HEAT

Since refrigeration deals entirely with the removal or transfer of heat, some knowledge of the nature and effects of heat is necessary for a clear understanding of the subject.

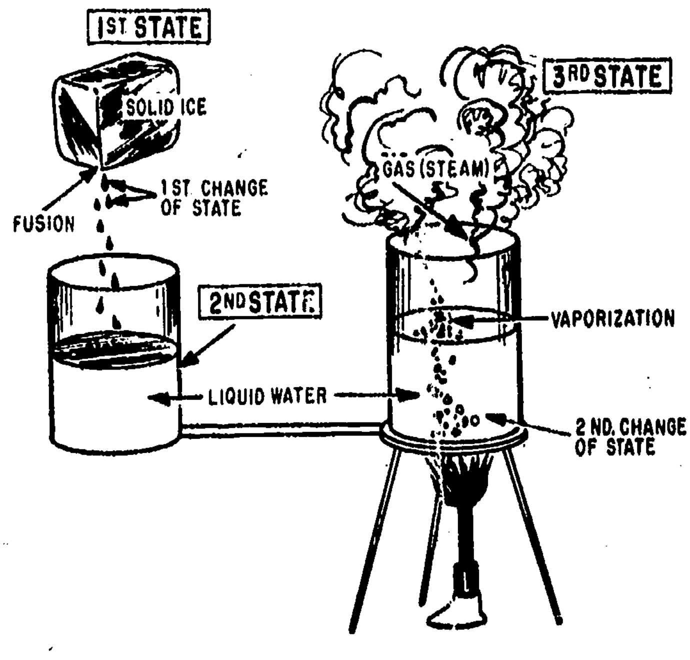
NATURE OF HEAT

Heat is a form of energy contained to some extent in every substance on earth. All known elements are made up of very small particles known as atoms which, when joined together, form molecules. These molecules are particular to the form they represent. For example, carbon and hydrogen in certain combinations form sugar and in others form alcohol.

Molecules are in constant motion. Heat is a form of molecular energy which results from the motion of these molecules. The temperature of the molecules dictates to a degree the molecular activity within a substance. For this reason, substances exist in three different states or forms: solid, liquid, and gas. Water, for example, may exist in any one of these states. As ice it is a solid; as water it is a liquid; and as steam it is a gas (vapor).

When heat is added to a substance the rate of molecular motion increases causing the substance to change from a solid to a liquid, and then to a gas (vapor). For example, in a cube of ice molecular motion is slow, but as heat is added molecular activity increases, changing the solid "ice" to a liquid "water." (See fig. 19-1.) Further application of heat forces the molecules to greater separation, and speeds up their motion to such an extent that the water changes into steam. The steam formed no longer has a definite volume such as a solid or liquid has, but will expand and fill whatever space is provided for it. Therefore, the molecular action in a substance is extremely active in the vapor state, while comparatively slow in the liquid state, and very slow in the solid state.

Heat cannot be destroyed or lost. However, it can be transferred from one body or substance to another, or to another form of energy. Since



54.144
Figure 19-1.—The three states of matter.

heat is not itself a substance it can best be considered in relation to its effect on substances or bodies. When a body or substance is stated to be cold, the heat which it contains is less concentrated or less intense than the heat in some warmer body used for comparison.

UNITS OF HEAT

It is believed that heat is the motion of molecules in a substance, or the internal friction produced by these molecules. The theory is that the speed of the molecules indicates the temperature or intensity of heat, while the number of molecules of a substance indicates the quantity of heat.

The intensity and quantity of heat may be explained in the following simple way. The water in a quart jar and in a 10-gallon container may have the same intensity or temperature, but the quantity of heat required to raise these amounts of water to a higher uniform temperature (from their present uniform temperature) will differ greatly. The 10-gallons of water will absorb a greater amount of heat than the quart jar of water.

The amount of heat added to, or subtracted from, a body can best be measured by the rise or fall in temperature of a known weight of a substance. The standard unit of heat measure is the amount of heat necessary to raise the temperature of 1 pound of water 1° F at sea level when water temperature is between 32° F and 212° F. Conversely, it is also the amount of heat that must be extracted to lower by 1° F the temperature of a pound of water between the same temperature limits. This unit of heat is called a British thermal unit (Btu). As the metric system becomes more widely used, another unit of heat measurement will become more common. This is the calorie and is the amount of heat required to raise one gram of water one degree centigrade.

Suppose that the temperature of 2 pounds of water was raised from 35° F to 165° F. To find the number of Btus required to increase the temperature, subtract 35 from 165. This equals 130 degrees temperature rise for 1 pound of water. Since 2 pounds of water were heated, multiply 130 by 2, which equals 260 Btus required to raise 2 pounds of water from 35° F to 165° F.

MEASUREMENT OF HEAT

The usual means for measuring temperature is by the use of a thermometer. It measures the degree or intensity of heat and usually consists of a glass tube with a bulb at the lower portion of the tube which contains mercury, colored alcohol, or a volatile liquid. The nature of these liquids causes them to rise or fall uniformly in the hollow tube with each degree of temperature change. Thermometers are used to calibrate the controls of refrigeration. The two most common thermometer scales are the Fahrenheit and centigrade.

On the Fahrenheit scale, there is a difference of 180 degrees between the freezing point (32) and the boiling point (212) of water. On the centigrade scale, you have only 100 degrees of difference between the same points (0 freezing and 100 boiling point).

Of course, a centigrade reading can be converted to a Fahrenheit reading, and vice versa. To change a centigrade reading to a Fahrenheit reading, multiply the centigrade reading by 1.8 and add 32°. This can be expressed in terms of the following formula:

$$F = (C \times 1.8) + 32$$

To change a Fahrenheit reading to a centigrade reading, subtract 32 from the Fahrenheit reading and then divide by 1.8. The formula which applies here is:

$$C = (F - 32) \div 1.8$$

TRANSFER OF HEAT

Heat flows from bodies of higher temperature to bodies of lower temperature in the same manner that water flows down a hill, and like water it can be raised again to a higher level so that it may repeat its cycle.

When two substances of different temperatures are brought in contact with each other, heat will immediately flow from the warmer substance to the colder substance. The greater the difference in temperature between the two substances, the faster the heat flow. As the temperature of both substances tend to equalize, the flow of heat will slow—and will stop completely when the temperatures are equalized. This characteristic of heat is utilized in refrigeration. The heat of the air, the lining of the refrigerator, and the food to be preserved is transferred to a colder substance called the refrigerant.

Heat, as a form of energy, cannot be destroyed. Bear in mind, though, that it can be transferred from one substance to another. Three methods by which heat may be transferred from a warmer substance to a colder substance are: conduction, convection, and radiation.

CONDUCTION is the method by which heat flows from a warmer substance to a colder substance when there is physical contact between them. It also is the method by which heat flows within solids. A cold metal bar placed against a red-hot metal bar will soon become too hot to hold at the end farthest from the source of heat, illustrating heat transfer from body to body and heat flow within a solid. Refrigeration makes use of this method of heat transfer in the cooling, for example, of canned foods. Here, the heat from the food is transferred by conduction to the can first, and the can's heat is transferred by conduction to the surrounding cold air in the refrigerator.

CONVECTION involves the transfer of heat within a fluid (liquid or gas) body. Here the flow of heat is caused by the natural motion of the heated substance itself—whether liquid or gas. Take a pan of boiling water as an example. When heated, the water becomes lighter and bubbles to the top of the pan and the cooler water on top, being heavier, falls to the bottom of the pan to be heated by conduction. This movement of the water by convection provides for more uniform heating of the pan of water. In refrigeration, convection explains how the heat from the air around the canned food is removed. The cooling device in a refrigerator is usually located in the upper portion of the space to be cooled and when the air surrounding it becomes cooled (by conduction) it becomes heavier and falls to the bottom of the space. The air there has been warmed by the canned food and, being lighter, rises to the cooling device.

In RADIATION, no material substance acts as a heat carrier. A person sitting near a hot stove is warmed by radiant heat even though the air between the person and the stove may remain cold. Similarly, radiant heat from the sun warms the earth without warming the space through which it passes. Radiant heat may pass through a transparent substance without warming it and is stopped or absorbed by an opaque substance. Radiant heat travels only in a straight line from its source and can best be reflected from a polished surface and absorbed by a dull black surface.

SPECIFIC HEAT

SPECIFIC HEAT is a term used to express the ratio between the quantity of heat required to change the temperature of 1 pound of any substance 1° F, as compared to the quantity of heat required to change 1 pound of water 1° F. The specific heat is thus numerically equal to the number of Btu's required to raise the temperature of 1 pound of a substance 1° F. For example, the specific heat of milk is .92, which means that 92 Btu's will be needed to raise 100 pounds of water 1° F. The specific heat of water is 1, by adoption as a standard, and the specific heat of another substance (solid, liquid or gas) is determined experimentally by comparing it to water. Specific heat also expresses the heat holding capacity of a substance compared to that of water. Table 19-1 gives the specific heat of a few common substances.

SENSIBLE HEAT AND LATENT HEAT

In the study of refrigeration, it is necessary to distinguish between sensible heat and latent heat. SENSIBLE HEAT is the term applied to the heat that is absorbed or given off by a substance which is NOT in the process of changing its physical state. When a substance is not in process of changing state, the addition or removal of heat always causes a change in the temperature of the substance.

Make it a point to remember that approximately .5 Btu of sensible heat is required to

Table 19-1.—Specific Heat of Some Common Substances

Solids		Liquids		Vapors	
Ice	0.504	Water	1.000	Steam	0.48
Iron	.130	Grain Alcohol	.648	Air	.24
Copper	.095	Oil	.45	Hydrogen	3.4
Lead	.031	Ammonia	1.1	Ammonia	.523
Glass	.194	Isobutane	.5	Isobutane	.4
Brick	.2	Methyl Chloride	.38	Methyl Chloride	.24

54.145

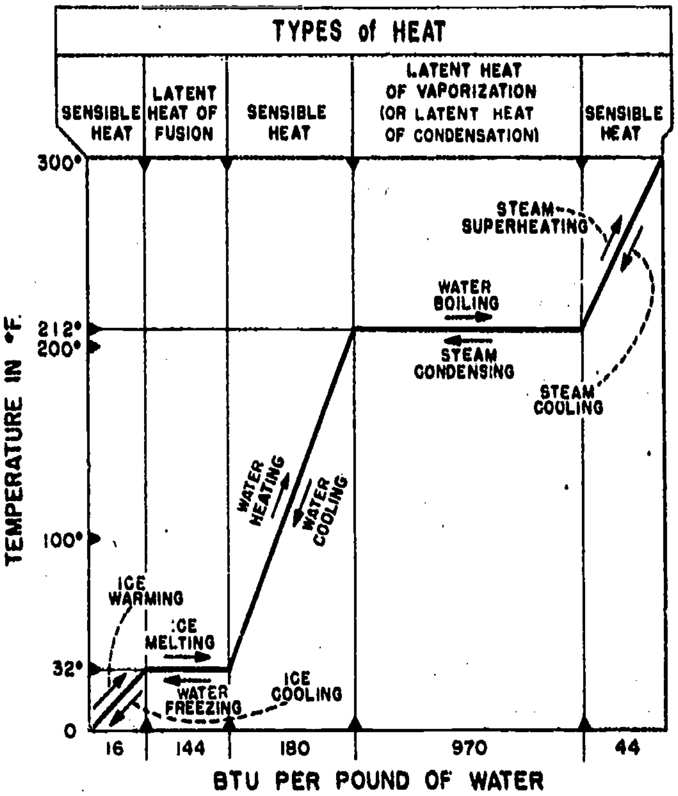
raise 1 pound of ice 1° Fahrenheit when the temperature is below 32° F; and approximately .5 Btu of sensible heat is required to raise 1 pound of steam 1° F above the temperature of 212° F.

LATENT HEAT, or hidden heat, is the term used to describe the heat that is absorbed or given off by a substance while it is changing its physical state. When a substance is in process of changing its physical state, the heat absorbed or given off does NOT cause a temperature change in the substance. In other words, sensible heat is the term used to describe heat that affects the temperature of things; latent heat is the term used to describe heat that affects the physical state of things.

In order to understand the concept of latent heat, you must realize that many substances may exist as solids, as liquids, or as gases, depending primarily upon the temperatures and pressures to which they are subjected. If the pressure is kept constant, the physical state of a substance will depend upon its temperature. To change a solid to a liquid, or a liquid to a gas, it is necessary to ADD HEAT, to change a gas to a liquid, or a liquid to a solid, it is necessary to REMOVE heat. The heat required to change the physical state of the substance, WITHOUT any change in temperature, is termed LATENT HEAT. You might say that latent heat is the price, in terms of heat energy, that must be paid for a change of state.

Suppose you take an uncovered pan of cold water and put it over a burner. The sensible heat of the water increases and so does the temperature. As you continue adding heat to the water in the pan, the temperature of the water will continue to rise until it reaches 212° F. Any addition of heat at this point causes the water to boil, and to change from a liquid state to a vaporous state; but the temperature remains at 212° F. What is happening? The water is now absorbing its latent heat of vaporization, and is changing from a liquid to a vapor. The heat required to change a liquid to a gas (or, on the other hand, the heat which must be removed from a gas in order to condense it to a liquid) without any change in temperature is known as the LATENT HEAT OF VAPORIZATION.

Now suppose you take another pan of cold water and put it in a place where the temperature is below 32° F. The water will gradually lose heat to its surroundings, and the temperature of the water will drop to 32° F. The temperature will remain at 32° F until all the water has changed to ice. While the water is changing to ice, however, it is still losing heat to its surroundings. The heat which must be removed from a substance in order to change it from a liquid to a solid (or, on the other hand, the heat which must be added to a solid in order to change it to a liquid) without change of temperature is called the LATENT HEAT OF FUSION.



38.1
Figure 19-2.—Relationship between temperature and the amount of heat required per pound (for water at atmospheric pressure).

It should be noted that the amount of heat required to cause a change of state (or, on the other hand, the amount of heat given off when a substance changes its state) varies according to the pressure under which the process takes place.

Figure 19-2 shows the relationship between sensible heat and latent heat for one substance, water, at atmospheric pressure. To raise the temperature of 1 pound of ice from 0° F to 32° F, it will be necessary to add only 16 Btu's. To change the pound of ice at 32° F to a pound of water at 32° F, it will be necessary to add 144 Btu's (the latent heat of fusion). There will be no change in temperature while the ice is melting. After all the ice is melted, however, the temperature of the water will be raised when additional heat is applied. If 180 Btu's (1 Btu for each degree of temperature increase between 32° and 212° F) are added, the water will boil. To change the pound of water at 212° F to a pound of steam at 212° F, you must add 970 Btu's (the latent heat of vaporization). After all the water is converted to steam at 212° F, the application of additional heat will cause a rise in the temperature of the steam. If you add 44 Btu's to the steam which is at 212° F, the steam will be superheated to 300° F.

TOTAL HEAT

Total heat is the sum of sensible and latent heat. Since measurements of the total heat in a certain weight of a substance cannot be started at absolute zero, a temperature is adopted at which it is assumed that there is no heat; and tables of data are constructed on that basis for practical use. Data tables giving the heat content of the most commonly used refrigerants start at 40° F below zero as the assumed point of no heat; tables for water and steam start at 32° F above zero. Tables of data usually contain a notation showing the starting point for heat content measurement.

DAY-TON OF REFRIGERATION

A day-ton of refrigeration (sometimes incorrectly called simply a ton of refrigeration) is the amount of refrigeration produced by melting one ton of ice at a temperature of 32° F in 24 hours. It is often used to express the amount of cooling produced by a refrigerator or air conditioner, as, for example, a one-ton air conditioner. A one-ton air conditioner will remove as much heat in 24 hours as will one ton of 32 degree F ice melting and becoming water at 32 degrees F. It is a rate of removing heat rather than a quantity of heat. Since it is a rate, it can be converted to Btu's per day, hour, or minute.

To find the rate (in Btu's per day), multiply 2000 (the number of pounds of ice in one ton) by Btu's (the latent heat of fusion per pound).

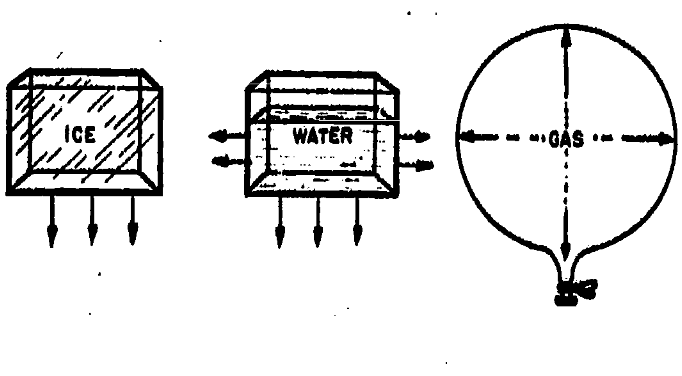


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Figure 19-3.—Exertion of pressures.

You will find that one day-ton of refrigeration equals 288,000 Btu's per day.

To calculate the rate per hour, divide the 288,000 Btu's per day by 24. The answer is 12,000 Btu's per hour. So that a "one-ton" air conditioner would have a rating of 12,000 Btu's.

Similarly, to find the rate per minute, divide 12,000 Btu's per hour by 60. Therefore, one day-ton of refrigeration is equivalent to 200 Btu's per minute.

PRESSURE

Pressure is defined as a force per unit area. It is usually measured in pounds per square inch (psi). Pressure may be in one direction, several directions, or in all directions, as illustrated in figure 19-3. The ice (a solid) exerts pressure downward only. The water (a fluid) exerts pressure on all wetted surfaces of the container. Gases exert pressure on all inside surfaces of their containers.

Pressure is usually measured on gages which may have one of two different scales. One scale is read as so many pounds per square inch gage (psig) and indicates the pressure above the atmospheric pressure surrounding the gage. The other type of scale is read as so many pounds per square inch absolute (psia) and indicates the pressure above absolute zero pressure (a perfect vacuum).

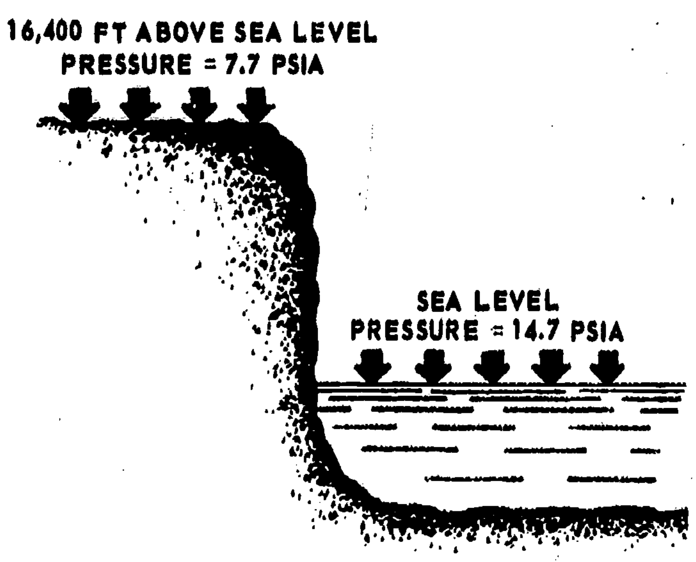

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Figure 19-4.—Atmospheric pressure.

ATMOSPHERIC PRESSURE

Atmospheric pressure is the pressure of the weight of the air above a point on, above, or under the earth. At sea level it is 14.7 psia, as shown in figure 19-4. As one ascends, the atmospheric pressure decreases approximately 1.0 psi for every 2343 feet. However, below sea level in excavations and depressions atmospheric pressure increases. Pressures under water differ from those under air only because the weight of the water above must be added to the pressure of the air.

SCALE RELATIONSHIPS

A definite relationship exists between the readings of a gage calibrated in psig and another, calibrated in psia. As shown in figure 19-5, when the psig gage reads 0, the psia gage will read the atmospheric pressure (14.7 psia at sea level). In other words, the psia reading equals the psig reading plus the atmospheric pressure (7.7 psia at 16,400 feet). Similarly, a psig reading equals the psia reading minus the atmospheric pressure.

For pressure less than the atmospheric pressure (partial vacuums), a measuring device with a scale reading in inches of mercury (Hg") or in inches of water (H_2O") is used. As can be seen from figure 16-5, a perfect vacuum is equal to -30 inches of mercury or -408 inches of water. In refrigeration work, pressures above atmospheric are measured in pounds per square inch, and pressures below atmospheric are measured in inches of mercury.

EFFECTS OF PRESSURE ON GASES

The exertion of pressure on a substance with a constant temperature will decrease its

ABSOLUTE SCALE (PSIA)	GAGE SCALE (PSIG)	INCHES OF MERCURY	INCHES OF WATER
44.7	30	NOT USED	NOT USED
24.7	10	NOT USED	NOT USED
14.7	0	0	0
0	NOT USED	-30	-408

54.336

Figure 19-5.—Pressure relationships.

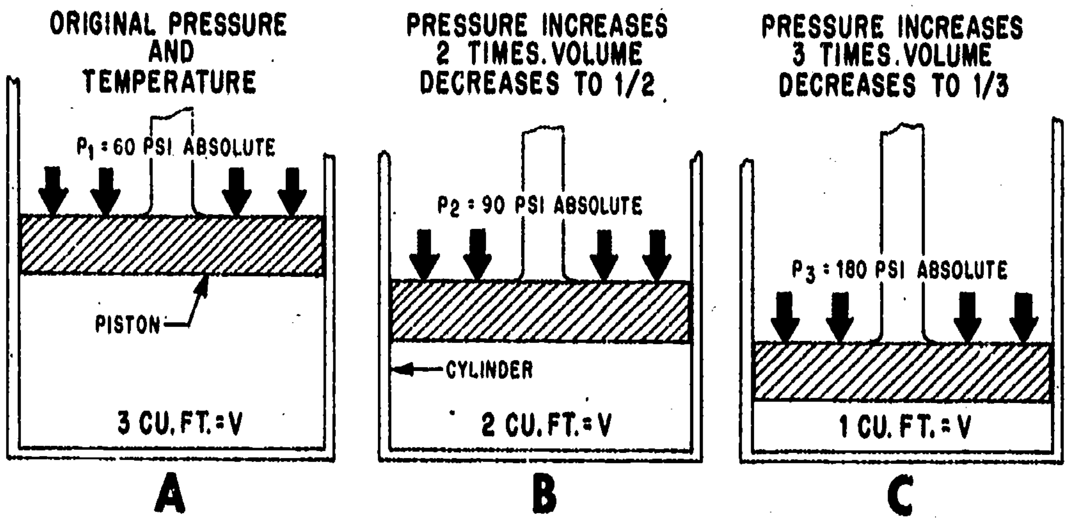

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Figure 19-6. — Pressure-volume relationship.

volume in proportion to the increase of pressure. For example, suppose that a given amount of gas is placed in a cylinder which is sealed on one end and has a movable piston on the other end. When 60 psi of absolute pressure is exerted on the piston, as shown in view A of figure 19-6, the volume of the gas will be compressed to 3 cubic feet. If 90 psi of absolute pressure is exerted on the piston, as shown in view B of

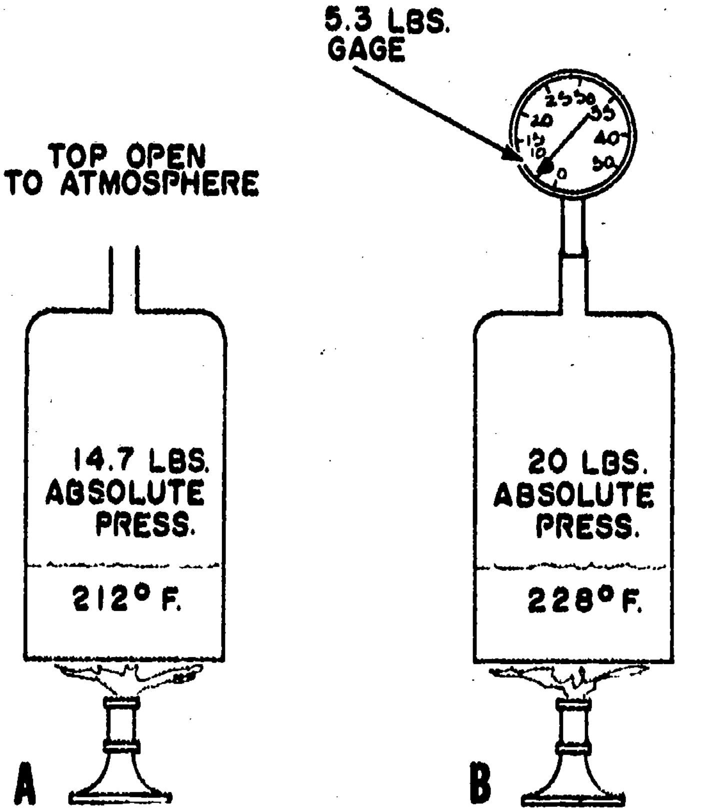

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Figure 19-7. — (A) Water boils at atmospheric pressure. (B) Water boils at 20 psi absolute pressure.

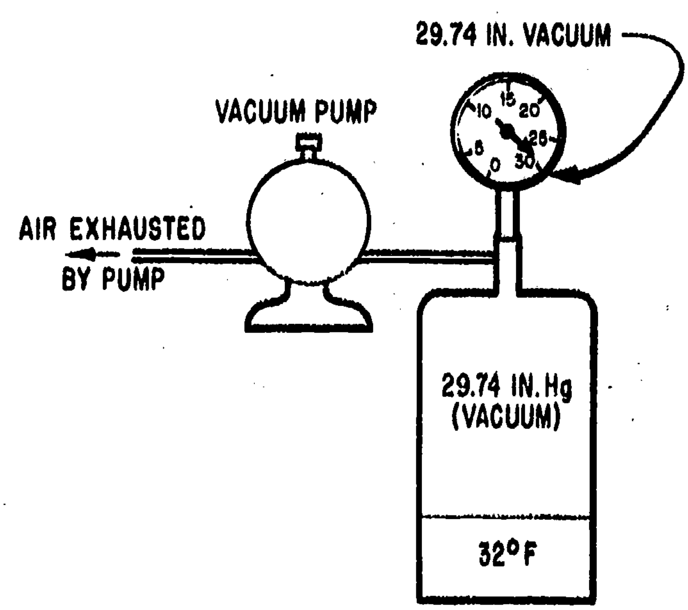

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Figure 19-8. — Water boils quicker in a vacuum.

Table 19-2.—Relation of Temperautre and Pressure

TEMP. °F	R-22 CHCLF2	R-12 CCl2F2	SULPHUR DIOXIDE SO2	AMMONIA NH3	METHYL CHLORIDE CH3Cl
-40	0.6 lbs.	10.9 in.	23.5 in.	8.7 in.	15.9 in.
-35	2.7 lbs.	8.4 in.	22.4 in.	5.4 in.	13.8 in.
-30	4.9 lbs.	5.5 in.	21.1 in.	1.6 in.	11.5 in.
-25	7.5 lbs.	2.3 in.	19.6 in.	1.3 lbs.	8.9 in.
-20	10.2 lbs.	0.6 lbs.	17.9 in.	3.6 lbs.	6.1 in.
-15	13.3 lbs.	2.4 lbs.	16.1 in.	6.2 lbs.	2.9 in.
-10	16.6 lbs.	4.5 lbs.	13.9 in.	9.0 lbs.	0.3 lbs.
- 5	20.3 lbs.	6.8 lbs.	11.5 in.	12.2 lbs.	2.1 lbs.
0	24.1 lbs.	9.2 lbs.	8.9 in.	15.7 lbs.	4.2 lbs.
+ 5	28.4 lbs.	11.8 lbs.	5.9 in.	19.6 lbs.	6.5 lbs.
10	32.9 lbs.	14.7 lbs.	2.6 in.	23.8 lbs.	8.9 lbs.
15	38.5 lbs.	17.7 lbs.	0.5 lbs.	28.4 lbs.	11.6 lbs.
20	43.3 lbs.	21.1 lbs.	2.5 lbs.	33.5 lbs.	14.5 lbs.
25	49.1 lbs.	24.6 lbs.	4.6 lbs.	39.0 lbs.	17.6 lbs.
30	55.2 lbs.	28.5 lbs.	7.0 lbs.	45.0 lbs.	21.0 lbs.
35	61.8 lbs.	32.6 lbs.	9.6 lbs.	51.6 lbs.	24.6 lbs.
40	69.0 lbs.	37.0 lbs.	12.4 lbs.	58.6 lbs.	28.6 lbs.
45	76.7 lbs.	41.7 lbs.	15.5 lbs.	66.3 lbs.	32.8 lbs.
50	84.7 lbs.	46.7 lbs.	18.8 lbs.	74.5 lbs.	37.3 lbs.
55	93.3 lbs.	52.0 lbs.	22.4 lbs.	83.4 lbs.	42.1 lbs.
60	102.5 lbs.	57.7 lbs.	26.2 lbs.	92.9 lbs.	47.3 lbs.
65	112.3 lbs.	63.7 lbs.	30.4 lbs.	103.1 lbs.	52.8 lbs.
70	122.5 lbs.	70.1 lbs.	34.9 lbs.	114.1 lbs.	58.7 lbs.
75	133.4 lbs.	76.9 lbs.	39.8 lbs.	125.8 lbs.	65.0 lbs.
80	145.0 lbs.	84.1 lbs.	45.0 lbs.	138.3 lbs.	71.6 lbs.
85	157.2 lbs.	91.7 lbs.	50.6 lbs.	151.7 lbs.	78.6 lbs.
86	159.5 lbs.	93.2 lbs.	51.8 lbs.	154.5 lbs.	80.0 lbs.
90	170.1 lbs.	99.6 lbs.	56.6 lbs.	165.9 lbs.	86.0 lbs.
95	183.6 lbs.	108.1 lbs.	62.9 lbs.	181.1 lbs.	93.8 lbs.
100	197.9 lbs.	116.9 lbs.	69.8 lbs.	197.2 lbs.	102.0 lbs.
105	212.9 lbs.	126.2 lbs.	77.2 lbs.	214.2 lbs.	110.7 lbs.
110	228.7 lbs.	136.0 lbs.	85.1 lbs.	232.3 lbs.	119.8 lbs.
115	252.1 lbs.	146.5 lbs.	93.3 lbs.	251.5 lbs.	129.5 lbs.
120	262.6 lbs.	157.1 lbs.	101.8 lbs.	271.7 lbs.	139.5 lbs.

54.153

figure 19-6, the volume of the gas will be compressed to 2 cubic feet. Finally, if 180 psi of absolute pressure is exerted on the piston, as shown in view C of figure 19-6, the volume of the gas will be compressed to 1 cubic foot. Thus, if a given amount of gas is confined in a container and subject to changes of pressure, its volume will change so the product of volume multiplied by absolute pressure is always the same.

Pressure has a very definite relationship to the boiling point of a substance. There is a definite temperature at which a liquid will boil for every definite pressure exerted upon it. For instance, water will boil at 212° F at atmospheric pressure (14.7 psia) as illustrated in view A, figure 19-7. The same water will boil at 228° F if the pressure is raised 5.3 psig (20 psia), as illustrated in view B, figure 19-7. On the other hand, the same water will boil

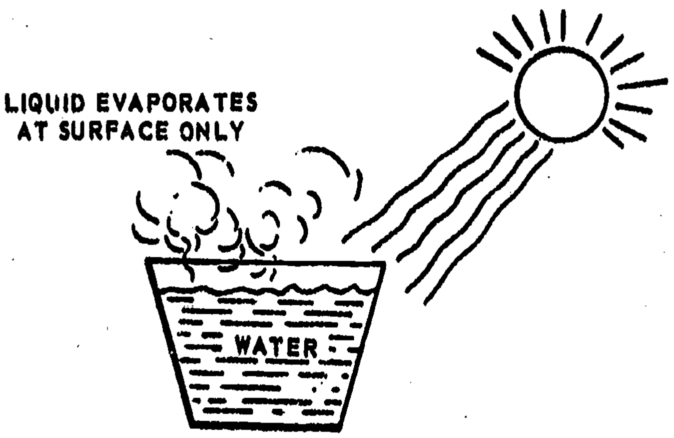

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Figure 19-9. — Normal surface evaporation.

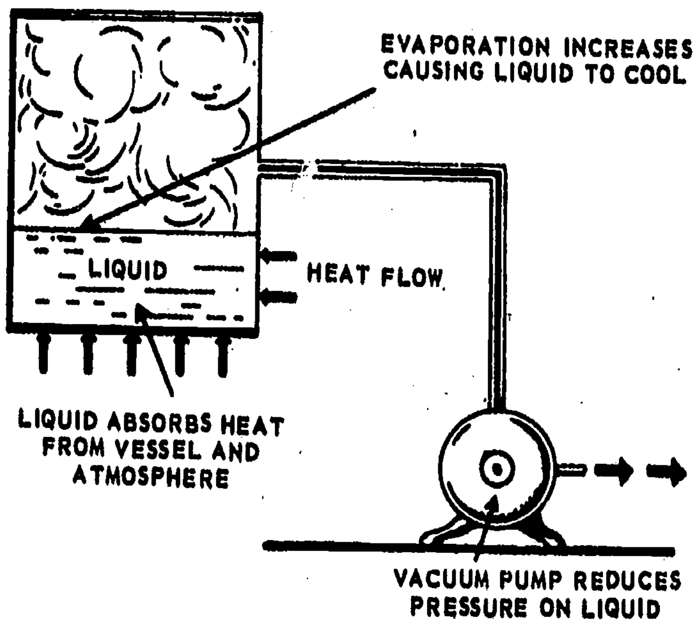

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Figure 19-10. — Evaporation by pressure reduction.

at 32° F in a partial vacuum of 29.74 inches of mercury (Hg) as illustrated in figure 19-8.

It is this effect of reduced pressure on the boiling temperature of refrigerants that makes the operation of a refrigeration system possible. For instance, the pressure temperature relationship chart in table 19-2 gives the pressures for several different refrigerants.

In table 19-2 note that liquid sulfur dioxide (SO_2) at any given temperature requires a certain and definite amount of pressure to keep it in a liquid state. When a cylinder of SO_2 is placed in a room at 20° F, and allowed to remain in the room until the temperature of the liquid is exactly 20° F the corresponding gage pressure will be 2.5 psi.

If the same container is placed in a room which has a temperature of 55° F, then the SO_2 will have a pressure of 22.4 psi. When the container is returned to the room having a temperature of 20° F and allowed to remain there until it cools down to the exact temperature of the room, the pressure will drop down to 2.5 psi again.

Thus, an increase in temperature of refrigerants results in an increase in pressure, and a decrease in temperature causes a decrease in pressure. By the same token, a decrease in pressure results in a corresponding decrease in temperature.

This means that as the pressure of a refrigerant is increased, so is the temperature at which the refrigerant boils. Thus, by regulating the pressure of a refrigerant, the temperature at which evaporation takes place and at which the latent heat of evaporation is utilized can be controlled.

VAPORIZATION

Vaporization is the process of changing a liquid to vapor, either by evaporation or boiling. If a glass is filled with water, as shown in figure 19-9, and exposed to the rays of the sun for a day or two, it will be noticed that the water level will drop gradually. The loss of water is due to evaporation. Evaporation, in this case takes place only at the surface of the liquid. It is gradual but the evaporation of the water can be speeded up if additional heat is applied to it. In this case the boiling of the water takes place throughout the interior of the liquid. Thus, the absorption of heat by a liquid causes it to boil and evaporate.

Vaporization can also be increased by reducing the pressure on the liquid, as illustrated in figure 19-10. Pressure reduction lowers the temperature at which the liquid boils, and hastens its evaporation. When a liquid evaporates, it absorbs heat from warmer surrounding objects and cools them. Refrigeration by evaporation is based on this method. The liquid is allowed to expand under reduced pressure, vaporizing, and extracting heat from the container (freezing compartment) as it changes from a liquid to a gas. After the gas is expanded (and heated), it is compressed, cooled, and condensed into a liquid again.

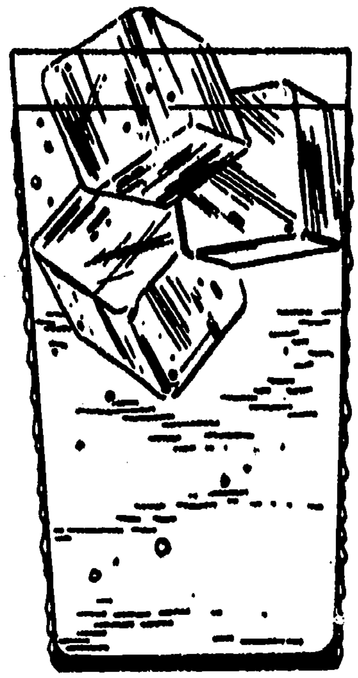

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Figure 19-11.—Condensation of moisture on a glass of cold water.

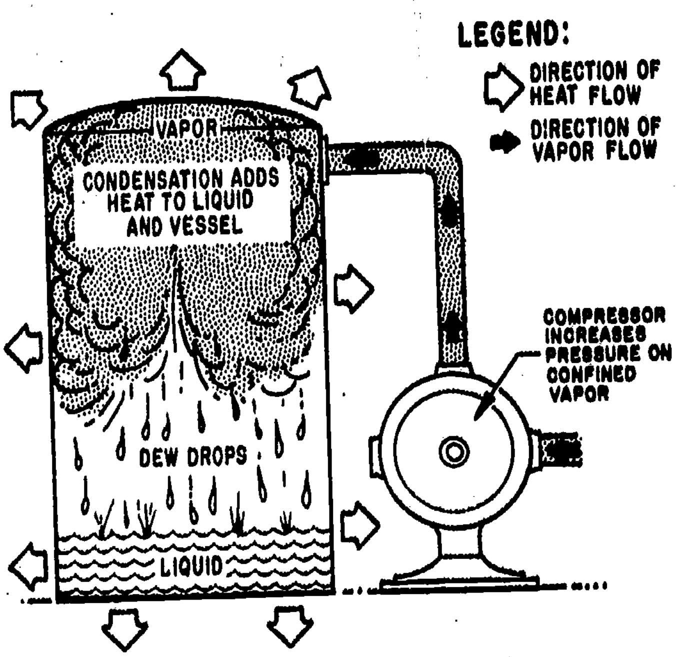

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Figure 19-12.—Pressure causes a vapor to condense.

CONDENSATION

Condensation is the process of changing a vapor into a liquid. For example, in figure 19-11, a warm atmosphere gives up heat to a cold glass of water, causing moisture to condense out of the air and form on the outside surface of the glass. Thus, the removal of heat from a vapor causes the vapor to condense.

An increase in pressure on a confined vapor also causes the vapor to change to a liquid. This fact is illustrated in figure 19-12. When the pressure on the vapor is increased by the compressor, the condensing vapor changes to a liquid and gives up heat to the cooler surrounding objects and atmosphere.

These conditions exist when the vaporized refrigerant is compressed by the compressor of a refrigeration system, and forced into the condenser. The condenser removes the superheat, latent heat of vaporization, and in some cases, sensible heat from the refrigerant.

MECHANICAL REFRIGERATION SYSTEMS

Mechanical refrigeration systems are an arrangement of components in a system that puts the theory of gases discussed up to this part in the chapter into practice to provide artificial cooling. To do this, it must provide (1) a metered supply of relatively cool liquid under pressure, (2) a device in the space to be cooled which operates at reduced pressure so that when the cool, pressurized liquid enters it will expand, evaporate, and take heat from the space to be cooled, (3) a means of repressurizing (compressing) the vapor, and (4) a means of condensing it back into a liquid, removing its superheat, latent heat of vaporization, and some of its sensible heat.

Every mechanical refrigeration system operates at two definite pressure levels. The dividing line is shown in figure 19-13. This line passes through the discharge valves of the compressor on one end and through the orifice of the metering device or expansion valve on the other.

The high pressure side of a refrigeration system includes all the components which operate at or above condensing pressure. These components include the discharge side of the compressor, the condenser, the receiver, and all interconnected tubing up to the metering device or expansion valve.

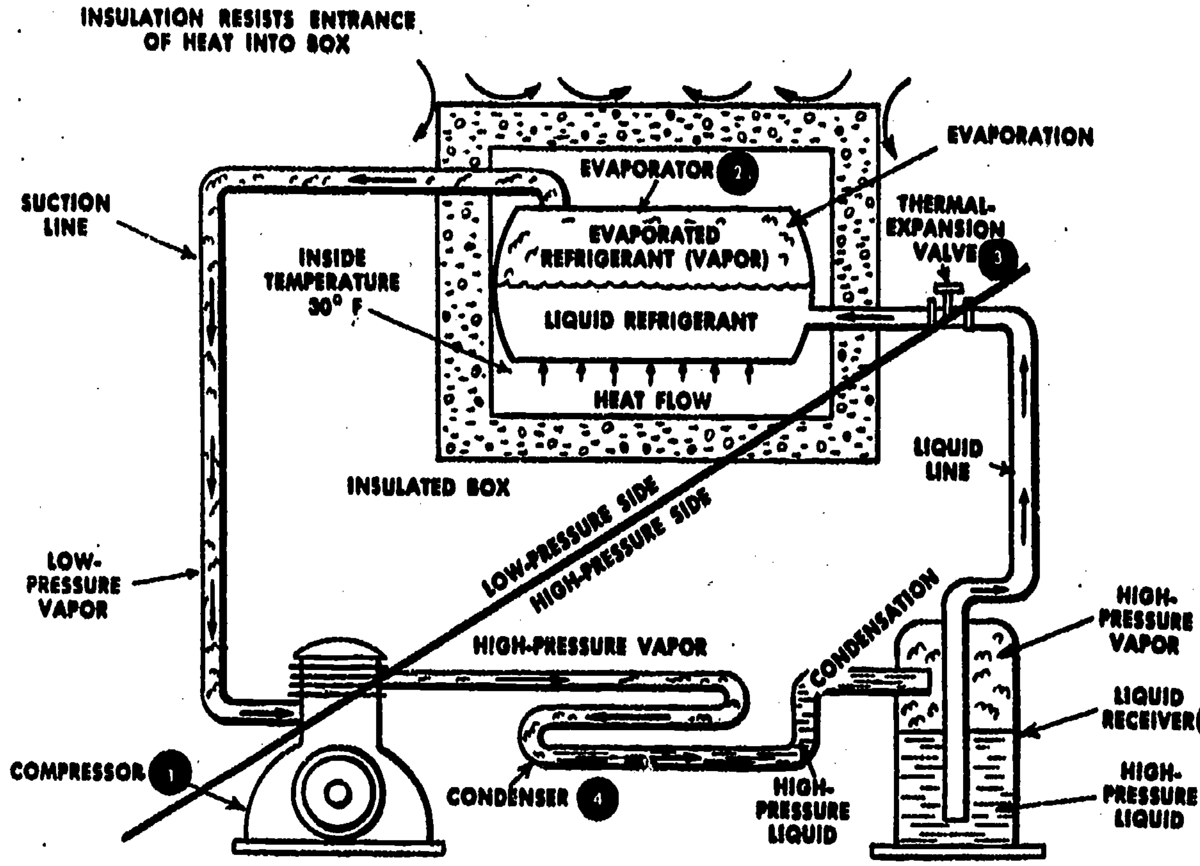

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Figure 19-13.—Refrigeration cycle.

The low pressure side of a refrigeration system includes all the components which operate at or below evaporating pressure. These components include the low pressure side of the expansion valve, the evaporator, and all the interconnecting tubing up to and including the low side of the compressor.

Refrigeration mechanics call the pressure on the high side "head pressure," "discharge pressure," or "high side pressure." On the low side the pressure is called "suction pressure," or "low side pressure."

The refrigeration cycle of a mechanical refrigeration system may be explained in the following manner, in conjunction with figure 19-13.

The pumping action of the compressor (1) draws vapor from the evaporator (2). This action reduces the pressure in the evaporator causing the liquid particles to evaporate. As the liquid particles evaporate this cools the evaporator. Both the liquid and vapor refrigerant tend to extract heat from the warmer objects in the insulated refrigerator cabinet. The ability of the liquid as it vaporizes to absorb heat is very high in comparison to that of the vapor. As the liquid refrigerant is vaporized, the low pressure vapor is drawn into the suction line by the suction action of the compressor (1). The evaporation of the liquid refrigerant would eventually remove all of the refrigerant from the evaporator if it were not replaced. The replacement of the liquid refrigerant is usually controlled by a metering device or expansion valve (3). This acts as a restrictor to the flow of the liquid refrigerant in the liquid line. Its function is to change the high pressure, subcooled liquid refrigerant to low pressure, low temperature liquid particles, which will continue the cycle by absorbing heat.

The refrigerant low pressure vapor drawn from the evaporator by the compressor through the suction line, in turn, is compressed by the compressor to a high pressure vapor which is forced into the condenser (4). In the condenser, the high pressure vapor condenses to a liquid under high pressure, and gives up heat to the condenser. The heat is removed from the condenser by the cooling medium of air or water. The condensed liquid refrigerant is then forced into the liquid receiver (5) and through the liquid line to the expansion valve by pressure created by the compressor, making a complete cycle.

Although the receiver is indicated as part of the refrigeration system in figure 19-13, it is not a vital component. The omission of the receiver, however, would necessitate having exactly the proper amount of refrigerant in the system. The refrigerant charge in systems not containing receivers is to be considered critical as any variations in quantity will materially affect the operating efficiency of the unit.

The refrigeration cycle of any refrigeration system must be clearly understood by a mechanic before he can repair the system. He must definitely understand how a refrigerant should be controlled so that it will absorb heat as it passes through the evaporator and give up heat as it passes through the condenser. By understanding the behavior of the refrigerant the malfunction of a refrigeration system can be detected more easily.

COMPONENTS OF MECHANICAL SYSTEM

The refrigeration system consists of four essential or basic parts. They are the compressor, condenser, control devices, and evaporator. Information on these parts is given below.

COMPRESSORS

Refrigeration compressors have but one purpose. This is to withdraw the head-laden refrigerant vapor from the evaporator and compress the gas to such a pressure that it will liquify in the condenser. The designs of compressors vary depending upon the application and type of refrigerant used in the system. There are three types of compressors classified according to the principle of operation. They are: reciprocating type, rotary type, and centrifugal type.

You may recall that material on compressors was presented in chapter 5 of this text. They will not be explained further here except for the special methods used to seal them to prevent the escape of refrigerant. Many refrigerator compressors have components in addition to those normally found on compressors, such as unloaders, oil pumps, mufflers, and so on. These devices are too complicated to explain in the limited space available here. Prior to repairing any compressor, check the manufacturer's manual for an explanation of their operation, adjustment, and repair.

Crankshaft Seals

A leak proof seal must be maintained where the crankshaft extends out of the crankcase of an open type compressor. The seal must be designed to hold the pressure developed inside of the compressor. It must prevent the refrigerant and compressor oil from leaking out, and prevent air and moisture from entering the compressor. For this purpose two different types of seals are commonly used. They are the stationary bellows seal and the rotating bellows seal.

An internal stationary bellows crankcase seal, shown in figure 19-14, consists of a corrugated thin brass tube (seal bellows) fastened

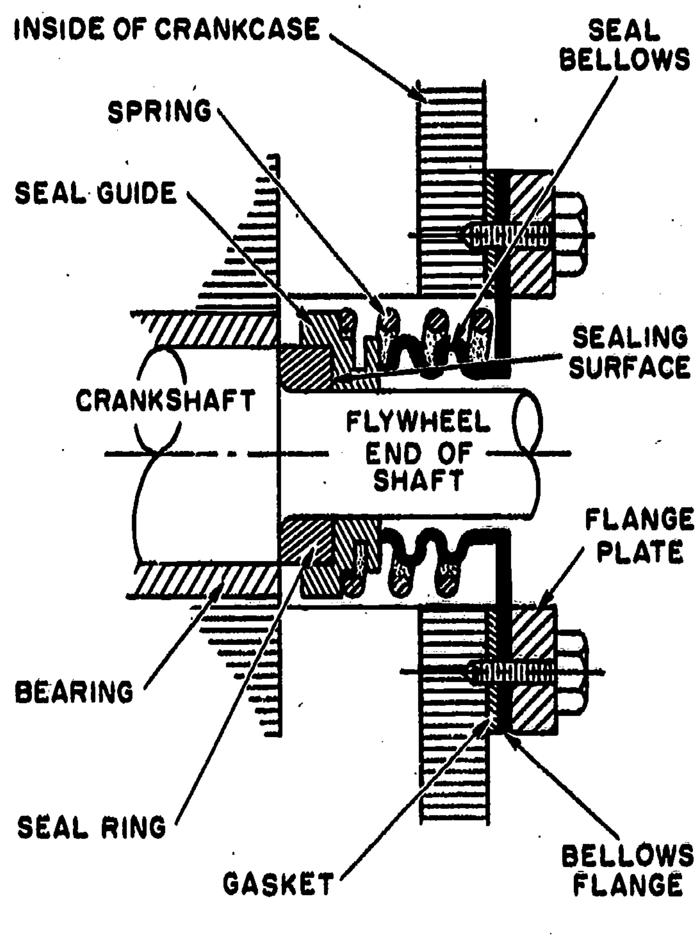

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Figure 19-14.—An internal stationary bellows crankshaft seal.

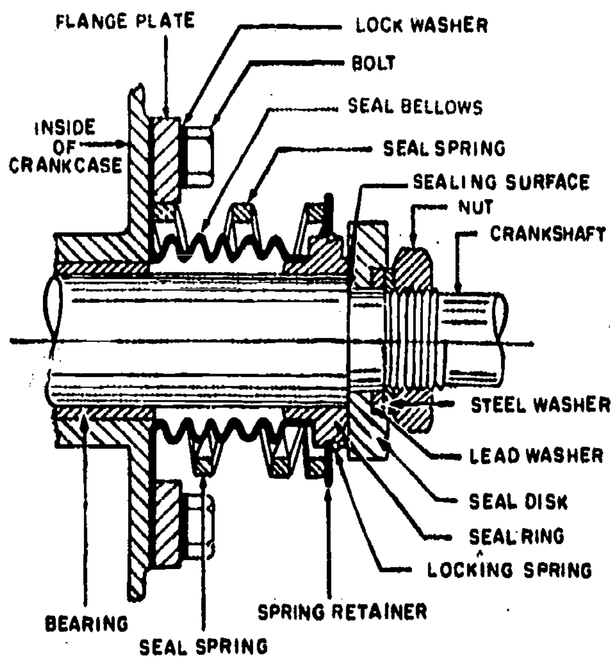

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Figure 19-15.—An external stationary bellows crankshaft seal.

to a bronze ring (seal guide) at one end, and to the flange plate at the other end. The flange plate is bolted to the crankcase with a gasket between the two units. A spring presses the seal guide mounted on the other end of the bellows against a seal ring positioned against the shoulder of the crankshaft. As the pressure builds up in the crankcase, the bellows tend to lengthen, causing additional force to

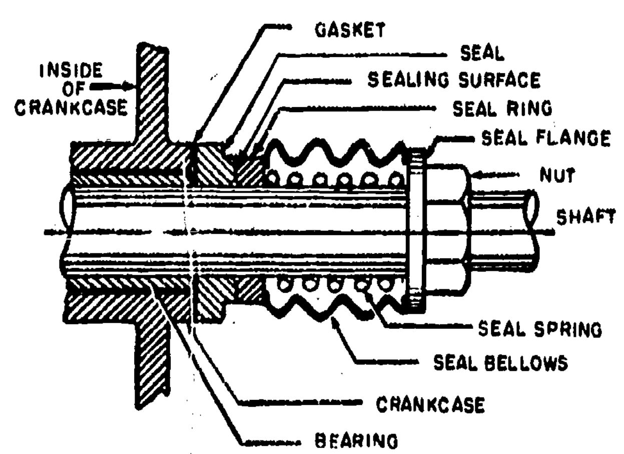

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Figure 19-16.—An external rotating bellows crankcase seal.

press the seal guide against the seal ring. Oil from the crankcase lubricates the surfaces of the seal guide and seal ring. The seal guide is accurately lapped to the seal ring so that the two surfaces form a gastight seal whether the compressor is running or is idle.

An external stationary bellows crankshaft seal is shown in figure 19-15. This seal is very similar to the internal bellows seal, except that it is positioned on the outside of the crankcase.

A diagram of a rotating bellows crankcase seal is shown in figure 19-16. This type of seal turns with the crankshaft. The rotating bellows seal also consists of a corrugated thin brass tube (seal bellows), with a seal ring fastened to one end and a seal flange fastened to the other. A seal spring is enclosed within the bellows. The complete bellows assembly slips on the end of the crankshaft and is held in place by a nut. The seal ring which is the inner portion of the bellows is positioned against a non-rotating seal that is fastened directly to the crankcase. The surfaces of the seal and seal ring are accurately lapped so that two surfaces form a gastight seal.

During operation, the complete bellows assembly rotates with the shaft, causing the seal ring to rotate against the stationary seal. The pressure of the seal spring holds the seal ring against the seal. The expansion of the bellows caused by the pressure from the crankcase also exerts additional pressure on the seal ring. Because of this design, a double pressure is exerted against the seal ring to provide a gastight seal between it and the stationary seal.

HERMETICALLY SEALED COMPRESSORS

The problem of prevention of leaks at the crankshaft seals of the open-type refrigeration compressor can be eliminated by the use of hermetically sealed compressors. In the design of open-type compressors, the shaft of an external electric motor is coupled to the compressor crankshaft, whereas, in the hermetically sealed unit, the electric motor and compressor are both in the same air-tight (hermetic) housing and share the same shaft. Figure 19-17 depicts a hermetically sealed unit—it should be noted that, after assembly, the two halves of the case are welded together to form an air-tight cover. Figure 19-18 shows an accessible type of hermetically sealed unit. The compressor, in this case, is a double piston reciprocating type having a crankshaft common to the electric

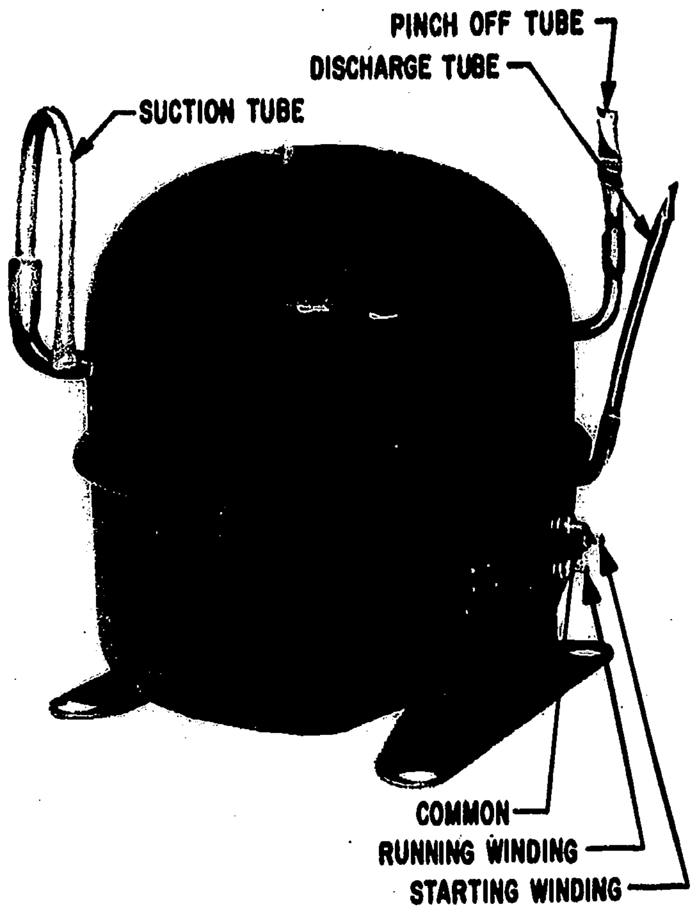

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Figure 19-17.—Nonaccessible hermetic compressor-motor.

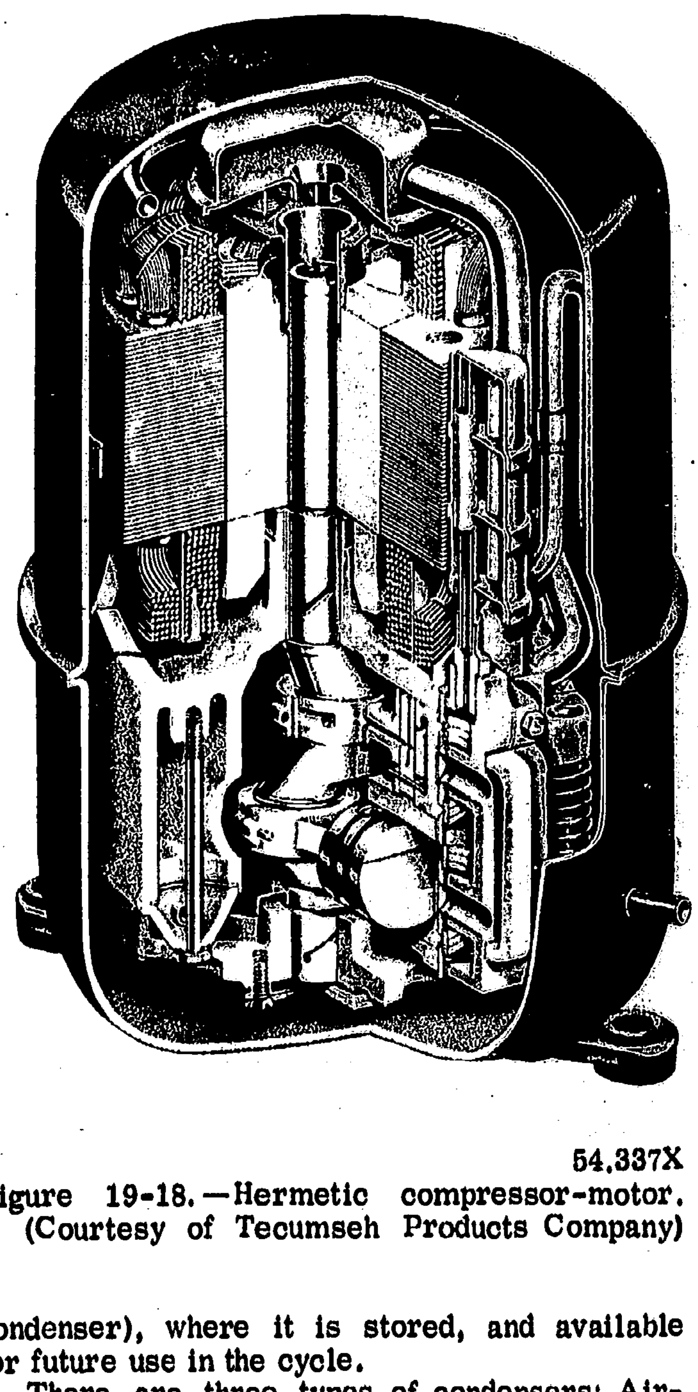

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Figure 19-18.—Hermetic compressor-motor. (Courtesy of Tecumseh Products Company)

motor in the righthand section. Other compressors may be of the centrifugal or rotary types. Cooling and lubrication are provided by the circulating oil, and the movement of the refrigerant vapor throughout the case.

The advantages of the hermetically sealed unit (elimination of the need for pulleys, belts, and other coupling methods and the elimination of a source of refrigerant leaks) is offset somewhat by the inaccessibility for repair and generally lower capacity.

CONDENSERS

The condenser in a refrigeration system removes and dissipates heat from the compressed vapor to the surrounding air or water in order to condense the refrigerant vapor to a liquid. The liquid refrigerant then falls by gravity to a receiver (usually located below the condenser), where it is stored, and available for future use in the cycle.

There are three types of condensers: Air-cooled, circulating-water-cooled, and evaporative condensers. The first two types are the most commmon but evaporative types are used where low quality water and its disposal make the use of circulating-water-cooled types unfeasible.

Air-Cooled Condenser

The construction of air-cooled condensers makes use of several layers of small tubing formed into flat coils. The external surface of this tubing is provided with fins to facilitate the transfer of heat from the condensing refrigerant

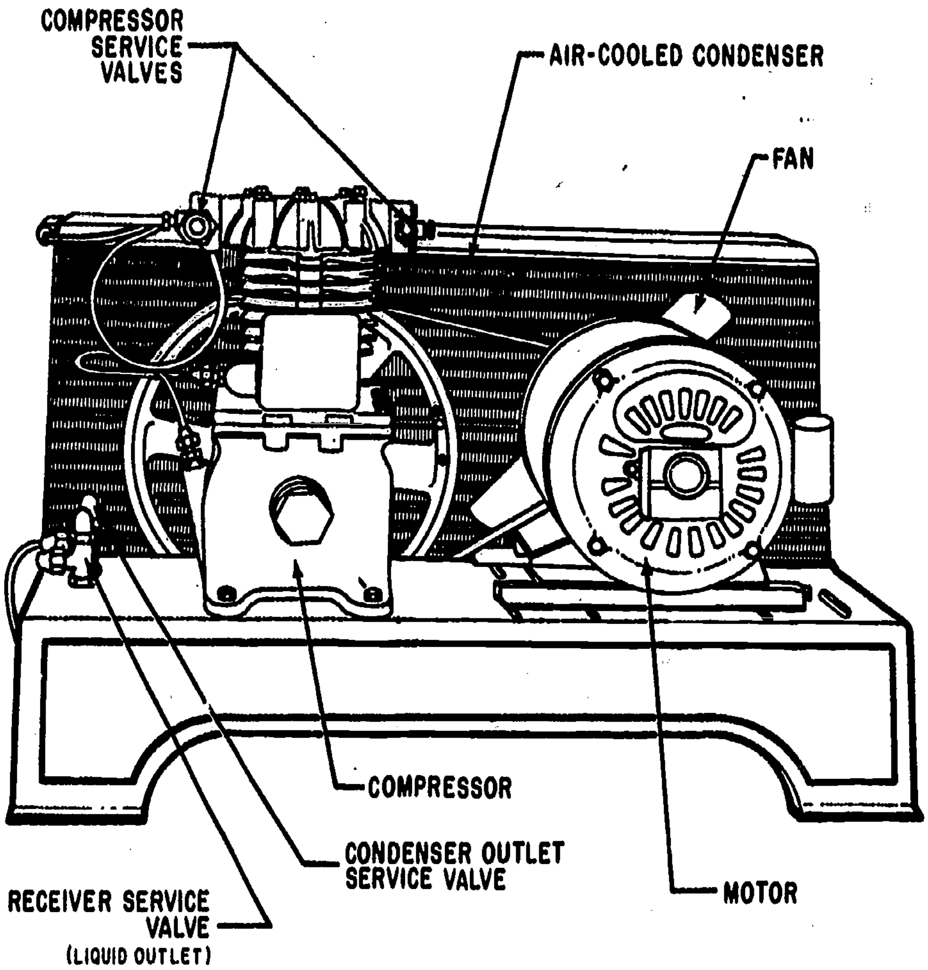

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Figure 19-19.—Air-cooled condenser mounted on compressor unit.

inside the tubes to the air circulated through the condenser core around the external surface of the tubes (see fig. 19-19). Condensation takes place as the refrigerant flows through the tubing and the liquid refrigerant is discharged from the lower ends of the tubing coils to a liquid receiver located on the condensing unit assembly.

Water-Cooled Condenser

Water-cooled condensers are of the multipass shell and tube type, with circulating water flowing through the tubes. The refrigerant vapor is admitted to the shell and condensed on the outer surfaces of the tubes. (See fig. 19-20.)

The condenser is constructed with a tube sheet brazed to each end of a shell. Copper-nickel tubes are inserted through drilled openings in the tube sheet and are expanded or rolled into the tube sheet to make a gas tight seal. Headers or water boxes are bolted to the tube sheet to complete the water side of the condenser. Zinc wasting bars are installed in the water boxes to minimize electrolytic corrosion of the condenser parts.

A purge connection with valve is located at the top side of the condenser shell to allow manual release of any accumulated air in the refrigerant circuit.

The capacity of the water-cooled condenser is affected by the temperature of the water, quantity of water circulated, and the temperature of the refrigerant gas. The capacity of the condenser will vary whenever the temperature difference between the refrigerant gas and the water is changed. An increased temperature difference or greater flow of water will increase the capacity of the condenser. The use of colder water can cause the temperature difference to increase.

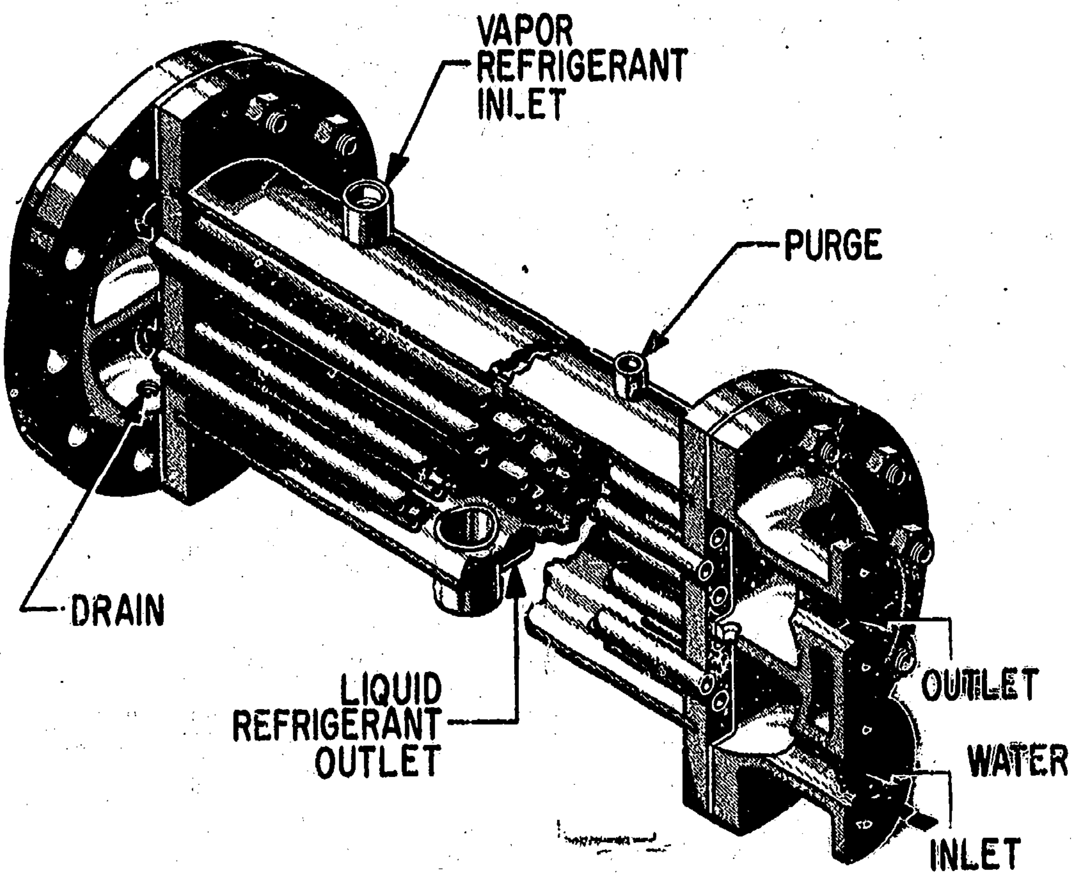

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Figure 19-20.—Water-cooled condenser.

Evaporative Condensers

An evaporative condenser operates on the principle that heat can be removed from condensing coils by spraying them with water or letting water drip onto them and then forcing air through the coils by a fan. This evaporation of the water will cool the coils and condense the refrigerant within them.

Liquid Receiver

A liquid receiver (see fig. 19-13) serves to accumulate the reserve liquid refrigerant, to provide a storage for off-peak operation, and to permit pumping down the system (information on pumping down is given later in this chapter). The receiver also serves as a seal against the entrance of gaseous refrigerant into the liquid line. When stop valves are provided at each side of the receiver for confinement of the liquid refrigerant, a pressure relief valve is generally installed between the valves in the receiver and condenser equalizing line to protect the receiver against any excessive hydraulic pressure being built up. Receivers should never be filled to exceed 80% to 90% of their total volume. If the pressure in the receiver should rise above the setting of the relief valve (usually about 225 psi) the relief valve will open and allow refrigerant to flow back into the condenser. Normally, on small units charged with F-12 or F-22 the relief valve vents to the atmosphere.

The receivers for units of very small capacity, equipped with air-cooled condensers, are frequently provided with FUSIBLE PLUGS or rupture disks in the end of the receiver shell. These fusible plugs replace the relief valves installed on larger units to protect the high pressure side of the unit from abnormal or excessive pressures. The fusible plug consists of a hollow shell surrounding a core plug of low melting point metal. Abnormally high pressures in the refrigerant system are accompanied by corresponding by high saturated refrigerant temperatures which melt the fusible core and relieve the pressure to the atmosphere.

EVAPORATORS

The evaporator is simply a bank or coil of tubing placed inside the refrigeration space. The tubing is filled with refrigerant at low pressure and low temperature. The refrigerant is in a liquid form as it enters the evaporator.

As the refrigerant circulates through the evaporator tubes, it absorbs its heat of vaporization from the surrounding space and substances. The absorption of this heat causes the refrigerant to boil. As the temperature of the surrounding space (and contents) is lowered, the liquid refrigerant gradually changes to a vapor. The refrigerant vapor then passes into the suction line by the action of the compressor.

Most evaporators used today are made of steel, copper, brass, stainless steel, aluminum, or almost any other kind of rolled metal that resists the corrosion of refrigerants and the chemical action of the foods.

There are two general types of evaporators, "flooded" and "dry." The inside of a dry evaporator coil is always filled with a mixture of liquid and vapor refrigerant. At the inlet side of the coil there is mostly liquid, but, as the refrigerant flows through the coil, it is vaporized until, at the end, there is nothing but vapor. In a flooded evaporator, a float level maintains liquid refrigerant at a constant level. As fast as the liquid refrigerant evaporates, more liquid is admitted by the float and, as a result, the entire inside of the evaporator is flooded with liquid refrigerant up to a certain level determined by the float.

Evaporators are classified according to the method of evaporation. They are the direct expanding type and the indirect expanding type.

The direct expanding type evaporator is one in which the heat is transferred directly from the refrigerating space through the tubes and absorbed by the refrigerant.

The indirect expanding type is one in which the refrigerant liquid or gas contained in the evaporator is used to cool some secondary medium, other than air. The secondary refrigerant is used to maintain the desired temperature of the refrigerated space. This is usually brine, which is a solution of calcium chloride, or a mixture of various chemicals of a low freezing point.

There are two methods of providing for the circulation of air within a refrigerated space. The cool air surrounding the evaporator must be moved to the stored food so that heat may be extracted by conduction and the warmer air from near the food must be returned to the evaporator to be cooled. Natural convection can be used by installing the evaporator in the uppermost portion of the space to be refrigerated so that the heavier cooled air will fall to the lower food storage section and the lighter food-warmed air will rise to the evaporator. In large refrigerated spaces it may be necessary to use fans to provide the additional movement of the air necessary to ensure that all areas are cooled.

CONTROL DEVICES

The effectiveness of modern refrigeration, for all systems, depends on automatic control. Automatic controls used with refrigeration systems usually provide for the control of the flow of liquid refrigerant, the on-off operation of the condenser cooling medium (such as water), and safety devices necessary for the prevention of damage to the equipment. Because a wide variety of devices are available for accomplishing the necessary control functions, it is impossible to consider each individual device in this discussion. However, the major classes of controls will be considered. (The UT should become familiar with the types of controls on the systems that are under his care.) There should be complete understanding of the manufacturer's instructions. You will find table 19-3 very useful in solving common control problems.

Control of Flow of Liquid Refrigerant

An expansion valve is a device used to control the flow of liquid refrigerant between the high side and the low side of the system. It is located at the end of the line between the condenser and the evaporator.

Constant-Pressure Expansion Valve

A constant-pressure expansion valve, also called an automatic expansion valve, maintains a constant pressure in the evaporator. A typical constant-pressure valve is shown in figure 19-21.

Normally, the constant-pressure expansion valve is used only with direct-expansion dry-type evaporators. In operation, the valve feeds a sufficient amount of liquid refrigerant to the evaporator to maintain a constant pressure in the coils. Because the temperature of the coils is dependent on the pressure, the temperature of the evaporator is governed by the expansion

Table 19-3. — Troubleshooting Checklist — Refrigeration Systems

TROUBLE	POSSIBLE CAUSE	CORRECTIVE MEASURE
High condensing pressure.	Air or non-condensable gas in system.	Purge air from condenser.
	Inlet water warm.	Increase quantity of condensing water.
	Insufficient water flowing through condenser.	Increase quantity of water.
	Condenser tubes clogged or scaled.	Clean condenser water tubes.
	Too much liquid in receiver, condenser tubes submerged in liquid refrigerant.	Draw off liquid into service cylinder.
	Insufficient cooling of air-cooled condenser	Check fan operation, cleanliness of condenser, and for adequate source of air flow
Low condensing pressure.	Too much water flowing through condenser.	Reduce quantity of water.
	Water too cold.	Reduce quantity of water.
	Liquid refrigerant flooding back from evaporator.	Change expansion valve adjustment, examine fastening of thermal bulb.
	Leaky discharge valve.	Remove head, examine valves. Replace any found defective.
High suction pressure.	Overfeeding of expansion valve.	Regulate expansion valve, check bulb attachment.
	Leaky suction valve.	Remove head, examine valve and replace if worn.
Low suction pressure.	Restricted liquid line and expansion valve or suction screens.	Pump down, remove, examine and clean screens.
	Insufficient refrigerant in system.	Check for refrigerant storage.
	Too much oil circulating in system.	Check for too much oil in circulation. Remove oil.
	Improper adjustment of expansion valves.	Adjust valve to give more flow.
	Expansion valve power element dead or weak.	Replace expansion valve power element.

54.189

Table 19-3. — Troubleshooting Checklist — Refrigeration Systems — Continued

TROUBLE	POSSIBLE CAUSE	CORRECTIVE MEASURE
Compressor short cycles on low pressure control.	Low refrigerant charge.	Locate and repair leaks. Charge refrigerant.
	Thermal expansion valve not feeding properly.	Adjust, repair or replace thermal expansion valve.
	(a) Dirty strainers.	(a) Clean strainers.
	(b) Moisture frozen in orifice or orifice plugged with dirt.	(b) Remove moisture or dirt (Use system dehydrator).
	(c) Power element dead or weak.	(c) Replace power element.
	Water flow through evaporators restricted or stopped. Evaporator coils plugged, dirty, or clogged with frost.	Remove restriction. Check water flow. Clean coils or tubes.
	Defective low pressure control switch.	Repair or replace low pressure control switch.
Compressor runs continuously.	Shortage of refrigerant.	Repair leak and recharge system.
	Leaking discharge valves.	Replace discharge valves.
Compressor short cycles on high pressure control switch.	Insufficient water flowing through condenser, clogged condenser.	Determine if water has been turned off. Check for scaled or fouled condenser.
	Defective high pressure control switch.	Repair or replace high pressure control switch.
Compressor will not run.	Seized compressor.	Repair or replace compressor.
	Cut-in point of low pressure control switch too high.	Set L.P. control switch to cut-in at correct pressure.
	High pressure control switch does not cut-in.	Check discharge pressure and reset H.P. control switch.
	1. Defective switch.	1. Repair or replace switch.
	2. Electric power cut off.	2. Check power supply.
	3. Service or disconnect switch open.	3. Close switches.

54.189

Table 19-3.—Troubleshooting Checklist—Refrigeration Systems—Continued

TROUBLE	POSSIBLE CAUSE	CORRECTIVE MEASURE
Compressor will not run. (Cont'd)	4. Fuses blown.	4. Test fuses and renew if necessary.
	5. Over-load relays tripped.	5. Re-set relays and find cause of overload.
	6. Low voltage.	6. Check voltage (should be within 10 percent of nameplate rating).
	7. Electrical motor in trouble.	7. Repair or replace motor.
	8. Trouble in starting switch or control circuit.	8. Close switch manually to test power supply. If OK check control circuit including temperature and pressure controls.
	9. Compressor motor stopped by oil pressure differential switch.	9. Check oil level in crankcase. Check oil pump pressure.
Sudden loss of oil from crankcase.	Liquid refrigerant slugging back to compressor crank case.	Adjust or replace expansion valve.
Capacity reduction system fails to unload cylinders.	Hand operating stem of capacity control valve not turned to automatic position.	Set hand operating stem to automatic position.
Compressor continues to operate at full or partial load.	Pressure regulating valve not opening.	Adjust or repair pressure regulating valve.
Capacity reduction system fails to load cylinders.	Broken or leaking oil tube between pump and power element.	Repair leak.
Compressor continues to operate unloaded.	Pressure regulating valve not closing.	Adjust or repair pressure regulating valve.

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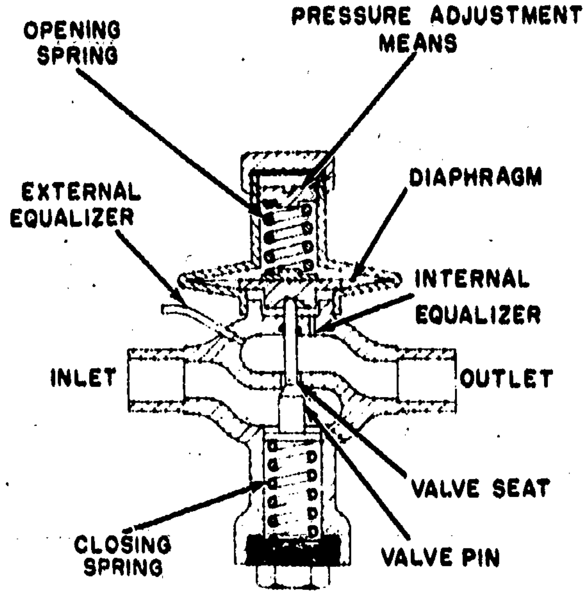
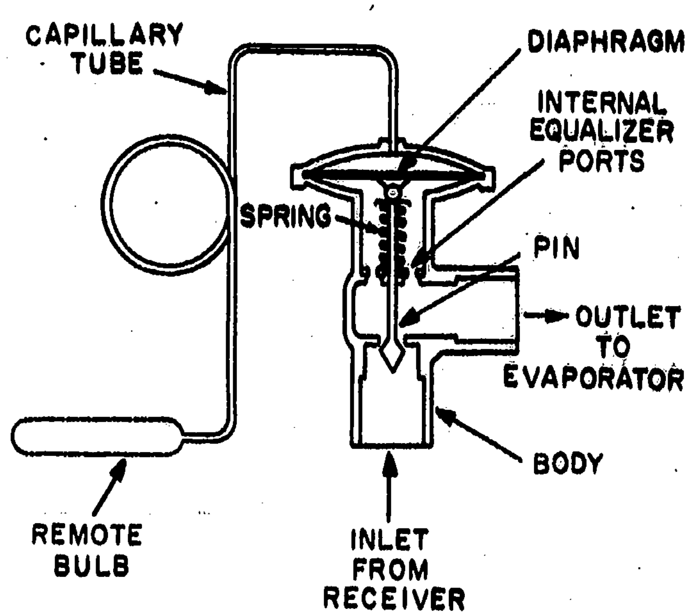


54.285X
Figure 19-21.—Constant-pressure expansion valve.



54.286
Figure 19-22.—Thermostatic expansion valve.

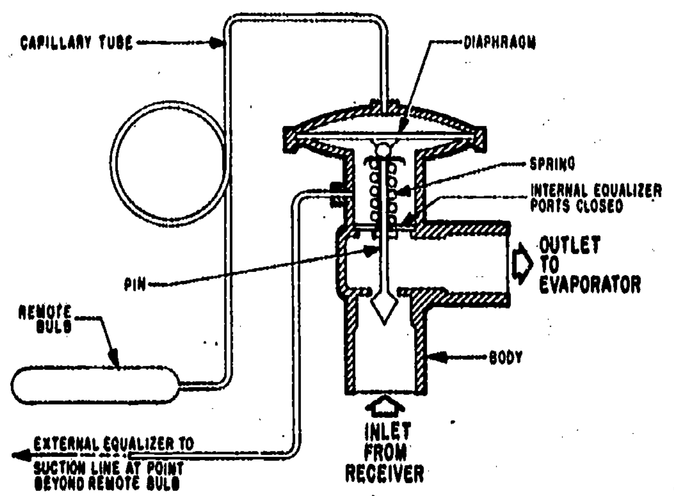
valve. This type of valve is generally used in a system where constant loads are expected. If a large variable load occurs and an automatic expansion valve is used, this valve will feed insufficient refrigerant to the evaporator under high load and will overfeed the evaporator at low load. Compressor damage can result if slugs of liquid enter the compressor. Consequently, maintenance personnel should be alert to the possible difficulties that may arise from an automatic expansion valve.

Thermostatic Expansion Valves

Before the operation of a thermostatic expansion valve can be discussed, the term "superheat" must be explained. A vapor gas is said to be superheated when its temperature is higher than the boiling point corresponding to its pressure. When the boiling begins, both the liquid and the vapor are at the same temperature. But in an evaporator, as the gas vapor moves along the coils toward the suction line, additional heat may be absorbed by the gas, and its temperature rises. The difference in degrees between the saturation temperature and the increased temperature of the gas is called superheat.

A thermostatic expansion valve (see fig. 19-22) tends to keep a constant superheat in the refrigerant vapor leaving the coil. This type of valve controls the flow of liquid refrigerant so that the evaporator coils are practically filled with liquid at all times. A thermostatic expansion valve has a power element activated by a remote bulb. The bulb senses the degree of superheat in the suction line and causes the valve to open or close. Thermostatic expansion valves may be provided with different remote bulb charges, two of which are the liquid charge and the gas charge. The conventional liquid charge employs the same refrigerant in the remote bulb as that used in the system proper. The remote bulb gas charge uses a limited amount of the same refrigerant that is used in the system. Manufacturers stamp or color code the valves to indicate exactly what type of charge must be used in the bulb. Notice the internal equalizer ports which cause the vapor pressure on the bottom of the diaphragm to be the same as that released into the evaporator.

As the superheat in the suction line increases, the temperature, and therefore the pressure, of the refrigerant in the remote bulb increases. This increased pressure, applied to the top of the diaphragm, forces it down along with the pin which opens the valve. Liquid refrigerant from the receiver is admitted to the evaporator replacing that extracted by the compressor suction. This replacement has three effects. First, it provides additional liquid refrigerant to absorb heat from the evaporator. Secondly, it applies higher pressure to the bottom of the diaphragm forcing it upwards and tending to close the valve.



54.286(54F)
Figure 19-23.—Thermostatic expansion valve having external equalizer.

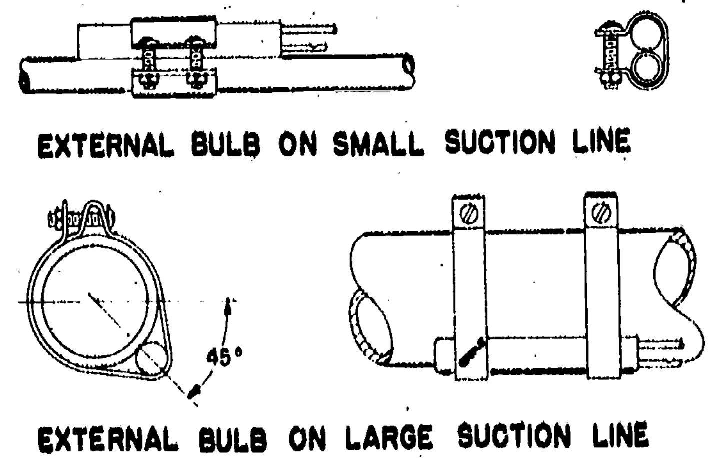
And thirdly, it reduces the degree of superheat in the suction line by flowing more refrigerant through it. When the valve closes too far restricting the refrigerant flow too much, the superheat rises and the cycle starts over. However, if the heat load remains constant, there will be little changing of the valve position. It will remain partially open to provide just the right amount of flow.

The use of internal equalizer ports, by applying the evaporator inlet pressure to the diaphragm, requires a greater degree of superheat to open the expansion valve than other means of equalization. The use of external equalization reduces the degree of superheat required to increase the opening of the valve by completing a line from the bottom of the diaphragm to the suction line, as in figure 19-23. This applies the lowest pressure in the system (suction pressure) to the bottom of the diaphragm and requires the least amount of pressure (and degree of superheat) on its top to open the valve. As you can see, this makes the thermostatic expansion valve with external equalization the most sensitive to load changes.

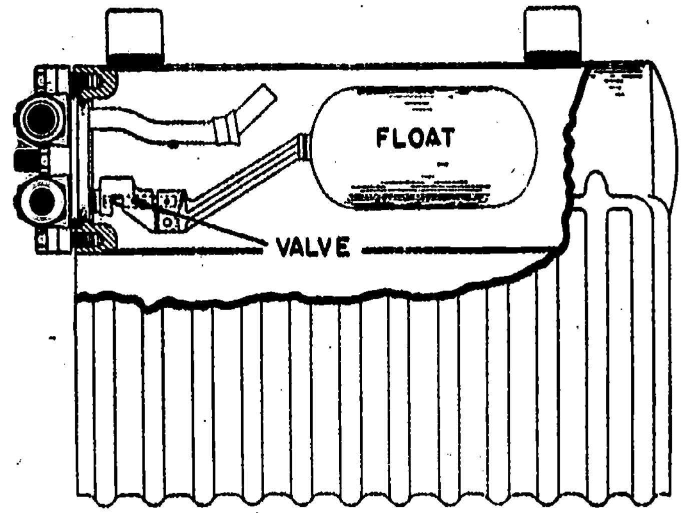
The expansion of the liquid passing through the valve causes a reduction in temperature. Thus, if any water is in the liquid refrigerant, freezing can occur and the valve will not function properly. To help prevent freezing, a drier is usually installed between the receiver and the evaporator. The drier is filled with a dehydrating agent such as silica gel or activated alumina, and serves to absorb moisture from the liquid refrigerant. If freezing of moisture in the expansion valve occurs, note the condition of the drier to see if it is absorbing moisture.

Care must be taken in the installation of the thermostatic expansion valve to ensure proper operation. The valve should be located so that it will be readily accessible for inspection and servicing. An upright position with power assembly on top is recommended. A gas-charged valve should be located so that the valve body temperature is warmer than the thermal element temperature. With the liquid charged valve, this precaution is not necessary.

Before applying heat to make up the soldered connections, remove the power assembly, cage assembly, and all gaskets. Keep heat away from all parts except the main body inlet and outlet connections. After reassembling the valve, the thermal element or bulb should be clamped tightly to the suction line from the cooling coil to make good metal to metal contact. The thermal element should be located close to the outlet of the cooling coil on a horizontal portion of suction pipe, using care to avoid locating it in any trapped portion. Where the suction pipe is under seven-eights-inch O.D., the thermal element should be located on top of the suction line. Where the suction line is seven-eighths-inch O.D. or larger, the thermal element should be located on the side of the pipe at a position equivalent to 4 o'clock as shown in figure 19-24. The bulb and pipe should be insulated together, the insulation extended over each side of the bulb. Improper contact and insulation or location



87.68
Figure 19-24.—Thermal element placement.

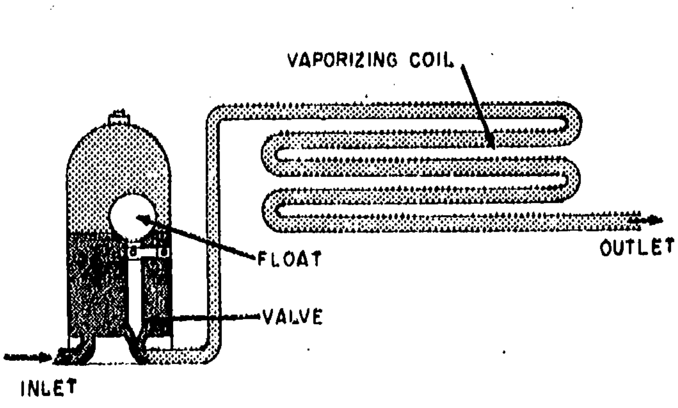


54.162
Figure 19-25.—A low-side float.

of the thermal element may cause liquid refrigerant flooding past the coil and may result in serious damage to the compressor.

Low-Side Float Valve

The low-side float valve is used to control the flow of liquid refrigerant where a flooded evaporator is used. It consists of a ball float located in either a chamber or the evaporator itself on the low-pressure side of the system. The float actuates a needle valve through a simple lever mechanism. (See fig. 19-25.) As the float lowers, refrigerant enters through the open valve; as the float rises, the valve closes. One maintenance problem with this type of control is the development of leaks in the ball float. If this occurs the float must be repaired or replaced, or a complete new valve assembly must be installed.



54.163
Figure 19-26.—A high-side float.

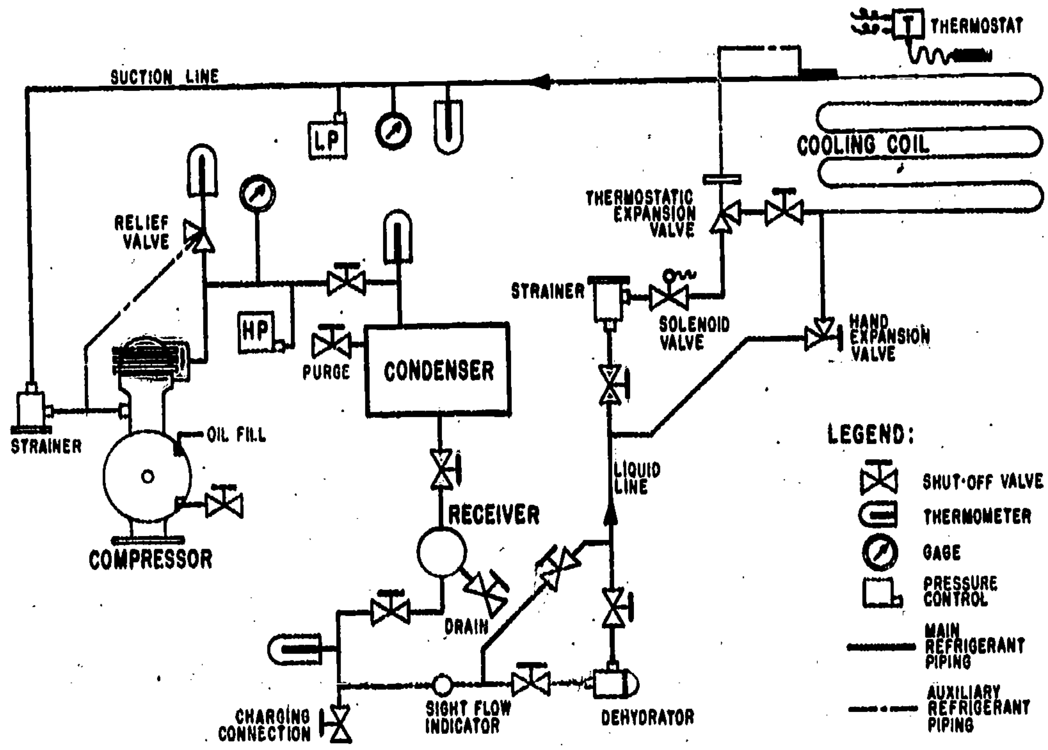
High-Side Float Valve

A high-side float expansion valve differs from the low-side control in that the valve float is located in a liquid receiver or in an auxiliary container on the high-pressure side of the system. (See fig. 19-26.) From the condenser, the liquid refrigerant flows into the high-pressure float valve, which immediately opens and allows the refrigerant to expand and pass into the evaporator. If the valve is equipped with a vent tube located inside the valve, then the float valve may be installed at a higher elevation than the condenser without danger of the chamber becoming gas bound. As a pointer on maintenance, refrigerant charge is critical. Refrigeration will be unsatisfactory with either an overcharge or an undercharge. Too much refrigerant will cause a floodback and the compressor may be damaged. Too little refrigerant will result in a opacity drop.

Capillary Tube

The capillary tube is another form of metering device. It consists of a long tube of small diameter. The length and diameter of the tube are very important; any restrictions will cause trouble in the system. The capillary tube is relatively simple in operation. There are no moving parts or adjustments. However, the capillary tube is best suited for household boxes—such as freezers and window air conditioners—where the refrigeration load is reasonably constant and small horsepower motors are used.

The capillary tube, as does the high-side float valve, feeds liquid refrigerant to the evaporator as fast as it is produced by the condenser. While the condensing unit is running (air cooled by a fan or water cooled by the circulation of water), the operating characteristics of the capillary-tube equipped evaporator are the same as if it were equipped with a high-side float. The compressor may be controlled with either pressure or temperature control. Evaporators equipped with a capillary tube may not be paralleled on one condensing unit. The charge of refrigerant is balanced in the same way as with a high-side float.



54.166

Figure 19-27.—A basic refrigeration system.

Unlike the high-side float valve, the capillary tube does not close when the compressor stops. If the quantity of refrigerant in the system is correct, that is, if the charge is balanced, the flow of liquid refrigerant from condenser to evaporator ceases promptly after the compressor unit stops. A high-side float closes as soon as liquid is no longer available and the high-pressure side is separated from the low-pressure side of the system during idle cycle. When the compressor unit stops on a capillary tube system, liquid continues to flow as long as it lasts, after which hot high-pressure gas from the condenser flows into the evaporator until pressures are equalized. Because the evaporator is cold, hot gas condenses in the evaporator and evaporator pressure rises slightly because of the heat of the hot gas. Equalization of pressure between evaporator and condenser makes starting of the compressor easy because there is not great pressure difference across the compressor at the time of starting. Low-starting-torque motors may be used with capillary tube systems just as if the compressor were equipped with an unloading device between discharge and suction sides of the compressor.

Exercise care to prevent restrictions in the tubes, and be certain that the proper refrigerant charge is used. Normally, capillary tubes are installed at the factory on package units. They are most often found on hermetically sealed units.

ACCESSORY DEVICES

The four basic or major parts of a refrigeration system just described are all that is necessary for a refrigeration unit to function. However, additional devices, such as the receiver already described, are necessary for a smoother and controlled cycle.

First we need a source of power (which is usually electrical) to drive the motor, which in turn operates the compressor that moves the refrigerant through its cycle. In chapter 6, motors were introduced and discussed briefly. Some of the other devices used on a refrigeration unit are briefly described in the following paragraphs in this section. Before proceeding, however, take a close look at figure 19-27, which shows one type of refrigeration system, with additional devices installed. Starting at the compressor, (high side pressure) we will explain some of the devices and their function. This will help you to understand the installation and trouble shooting of a refrigeration unit.

RELIEF VALVE

A spring loaded relief valve is installed in the compressor discharge line between the compressor discharge connection and the discharge line stop valve to protect the high pressure side of the system from excessive pressures. This valve is located internally in some compressors as an integral part. The discharge from the relief valve is led to the compressor suction line and in the event that the compressor discharge pressure becomes abnormally high from any cause, the relief valve opens and bypasses the discharged gas to the suction side of the compressor.

DISCHARGE PRESSURE GAGE AND THERMOMETER

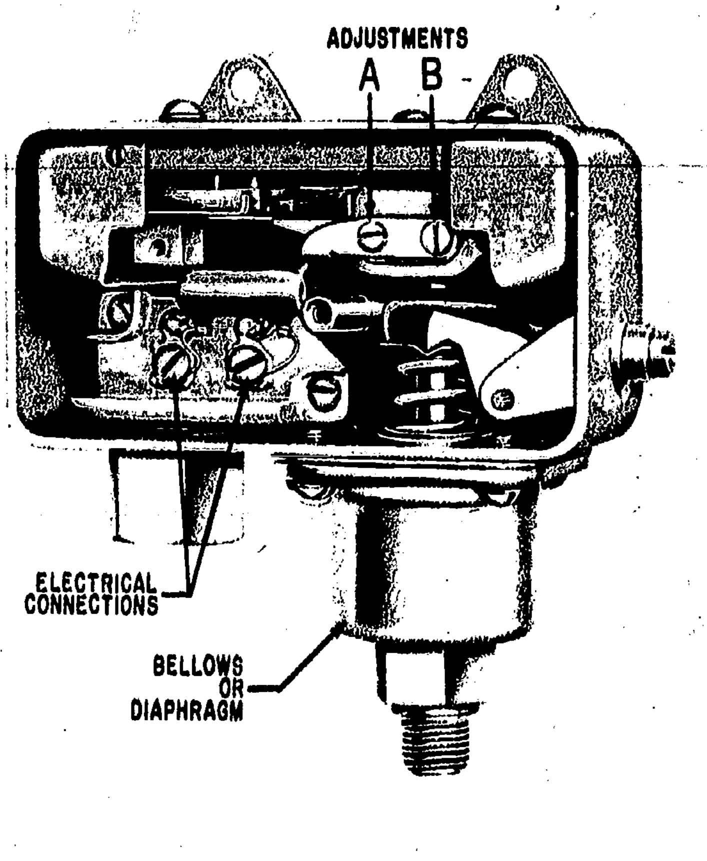
A pressure gage and thermometer are installed in the compressor discharge line to indicate the pressure and temperature of the compressed refrigerant gas. The temperature indicated is always higher than that corresponding to the pressure when the compressor is in operation, due to the initial condition of the compressor suction vapor and the work of compression applied to the refrigerant gas during the process of compression.

The compressor discharge line terminates at the refrigerant condenser.

COMPRESSOR-MOTOR CONTROLS

The starting and stopping of the compressor motor is usually controlled by either a pressure actuated or temperature actuated motor control. Temperature and pressure are directly related to each other. If the temperature of a refrigerant is increased, the pressure will increase; similarly, if the pressure changes, the temperature must also change. The operation of the pressure motor control depends on this relationship between pressure and temperature. A pressure motor control is shown in figure 19-28. The device consists of a low-pressure bellows, or in some cases a low-pressure diaphragm, that is connected by a small-diameter tube to the compressor crankcase or to the suction line. The pressure in the suction line or the compressor crankcase is transmitted through the tube and actuates the bellows or diaphragm. The bellows moves according to the pressure, and its movement causes an electric switch to either start or stop the compressor motor. Adjustments, in accordance with the manufacturer's instructions, can be made on the "cutout" and "cut-in" pressures. Usually the cutout pressure is adjusted to correspond to a temperature a few degrees below the desired evaporator coil temperature, and the cut-in pressure is adjusted to correspond to the temperature of the coil. If the difference between the cutout pressure and the cut-in pressure is large, a greater variation in cabinet temperature occurs. But with this large difference, the cycling time is increased. With a small pressure differential, the load or cabinet temperature will be more uniform and the cycling time shortened.

The temperature motor control is very much like the pressure device. The main difference is that a temperature-sensing bulb and a capillary tube replace the pressure tube. With the temperature motor control, the motor responds directly to the temperature in the cooled space. The cutout and cut-in temperature can be adjusted, and the difference between the two can be changed.



77.119
Figure 19-28. — Pressure actuated control.

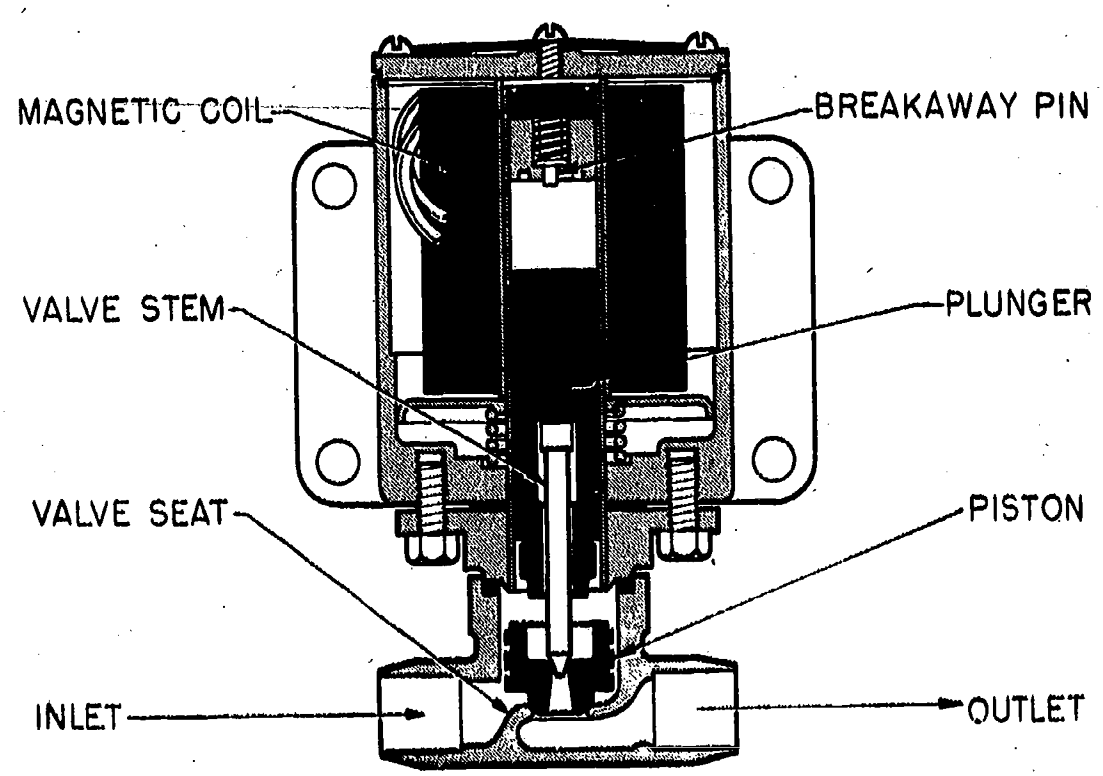
In addition, the refrigeration system may be equipped with a high pressure safety cutout switch that serves to shut off the power to the compressor motor when the high-side pressure exceeds a preset limit. The construction of the high-pressure cutout is similar to that of the pressure motor control. The pressure tube is usually connected to the cylinder block and is actuated by excessive head pressure. If pressure exceeds the control limit because of too little condenser water, excessive noncondensible gases in the system, or for any other cause, the system stops and damage is prevented.

Maintenance personnel seldom have to make repairs on compressor-motor controls. Normally, such repairs are made by the manufacturer. However, it is the responsibility of maintenance personnel to make correct adjustments on these controls to assure the smooth operation of the system. If the system must be shut down for repairs or maintenance work, the controls must be accurately set when the system is again placed in operation.

SOLENOID STOP VALVES

Solenoid stop valves, or magnetic stop valves as they are sometimes called, are used to control gas or liquid flow. They may be found in many locations throughout the system, but they are most commonly used to control the flow of liquid refrigerant to the expansion valve. The liquid-refrigerant line is open to passage of refrigerant only when the compressor is in operation and the solenoid is energized. This is because the compressor motor and the solenoid stop valve are electrically in parallel, that is, the electrical power is applied to or removed from both simultaneously by the motor control switch. Thus, leakage of liquid refrigerant into the evaporator is prevented when the compressor is not running. A typical solenoid stop valve is shown in figure 19-29.

Solenoid stop valves may not operate properly because of a burned-out solenoid coil. In this event, the coil is normally replaced by a new one. However, foreign material may become lodged between the stem and the seat, and the valve will then leak fluid. This condition may be mistaken for an electrically defective valve. Before a valve is replaced or discarded, it should be carefully checked to see if it is still useful. The solenoid valve must be installed in such a manner that the coil and plunger are in a true vertical position. If the valve is cocked the



47.98.1

Figure 19-29.—Solenoid valve.

plunger will not reseat properly, causing refrigerant leakage.

THERMOSTAT SWITCH

Occasionally, a solenoid stop valve is operated directly by a thermostat located in the refrigerated space, and the compressor motor is controlled independently by a low-pressure switch. In this case the thermostat can close the solenoid valve, which stops flow in the liquid line.

The solenoid valve control switch or thermostat makes and breaks the electrical circuit through the coil, thereby controlling the flow of liquid refrigerant to the expansion valve. The control bulb is charged with a refrigerant so that temperature changes of the bulb produce corresponding changes in the pressure of the actuating vapor within the control bulb. These pressure changes are transmitted through the control tubing to the switch power element, to operate the switch. The switch is adjusted to open the contacts and thus release the solenoid valve, stopping the flow of refrigerant to the cooling coil when the temperature of the refrigerated space has reached the desired point. The compressor, however, continues to operate until it has evacuated the evaporator. The resulting low pressure in the evaporator then activates the low-pressure switch, which stops the compressor. As the temperature rises, the increase in bulb pressure closes the switch contacts and refrigerant is supplied to the expansion valve.

A pressure operated motor controller may be used as a thermostat by the addition of a small diameter tube and a bulb, provided the tube and bulb are properly charged.

REFRIGERANT LIQUID LINE

The refrigerant liquid accumulated in the bottom of the receiver shell is conveyed to the cooling coils through the main refrigerant liquid line. A stop valve and thermometer are usually installed in this line adjacent to each receiver. Where the sight-flow indicator and dehydrator assembly are close to the receiver the built-in shutoff valves may be used in lieu of a separate shutoff valve.

DEHYDRATOR

A dehydrator or drier may be installed in the liquid line of a refrigeration system to remove moisture that would harm the system components and reduce efficiency. If installed permanently in the line, it will offer some resistance to flow and, for this reason, some manufacturers install it in a bypass line (see fig. 19-27).

A dehydrator consists of a tubular shell with suitable fittings on each end so that it may be connected to the liquid line. A strainer in each end prevents any drying material from escaping from the dehydrator into the system. Dehydrators containing zinc chips for neutralizing acidity of sulfur-dioxide refrigerating systems must not be used in R-12 or methyl chloride systems.

There are three approved desiccants (drying materials) for use in dehydrators. In order of preference they are: silica-gel, activated alumina, drierite (calcium sulfate). Silica-gel and activated alumina absorb moisture from the passing refrigerant, picking up water as does a sponge. Silica-gel and activated alumina are composed of millions of small pores. Drierite absorbs moisture, by chemical action when moisture comes into contact with it.

SIGHT FLOW INDICATOR

A sight flow indicator is installed in the liquid line. The sight flow indicator is a special fitting provided with a gasketed glass port on each side and furnished with seal caps for protection when not in use. While a single port indicator may be used, the double port unit permits the use of a flashlight background, where space is available, for a clearer view. The refrigerant may be viewed passing through the pipe to determine the condition of the liquid with respect to the presence and amount of vapor bubbles in the liquid which would indicate an inadequate supply of refrigerant or existence of unfavorable operating conditions.

SUCTION-LINE CONTROLS

Suction pressure regulators are sometimes placed between the outlet of the evaporator and the compressor to prevent the evaporator pressure from being drawn down below a predetermined level despite load fluctuations. These are usually installed in systems where the evaporator temperature is required to be higher than usual, such as in a milk cooler. If the evaporator pressure is allowed to drop too low, the corresponding temperature will be below that desired and freezing of the milk or frosting of the coils will result. Above the minimum pressure setting the regulator is wide open and has no effect but, as the pressure moves downward toward the setting, the regulator begins to close and automatically maintains the desired minimum pressure.

Suction pressure control switches, often called low pressure cutouts, are sometimes connected to a tee in the suction line. They are essentially a single-pole, single-throw electrical switch and mainly used control starting and stopping of the compressor. The refrigerant suction pressure acts on the metallic bellows of the power element of the switch and produces movement of a lever mechanism operating electrical contacts. A rise in pressure closes the switch contacts and thereby completes the pilot circuit of the motor controller which in turn starts the compressor automatically. As operation of the compressor gradually decreases the suction pressure, the movement of the switch linkage reverses until the contacts are separated at a predetermined low suction pressure, thus breaking the motor controller pilot circuit and stopping the compressor.

SUCTION LINE STRAINER

A suction strainer is provided at the compressor suction line connection to protect the moving parts of the compressor from dirt, scale, and filings, which may find their way into the refrigerant piping system when a system is opened due to initial installation, inspection, or maintenance. This strainer on late model compressors is located inside the compressor and removable through a flanged connection.

GAGES AND THERMOMETERS

Between the suction line stop valve and the compressor, a thermometer and a pressure gage maybe provided to indicate the suction conditions at which the compressor is operating. The thermometer will indicate a higher temperature than the temperature corresponding to the suction pressure, as indicated by the gage, because the refrigerant vapor becomes superheated during its passage from the evaporator to the compressor through the suction liquid heat exchanger (where used), and by heat leakage to the suction line insulation. All refrigerating plant gage lines are provided with cutout valves near the gage for use in case of derangement. Standard thermometers are employed and the thermometer wells may be of the screwed type. The threaded joint is seal welded or silver brazed to a piping system fitting to prevent leakage.

ACCUMULATORS AND OIL SEPARATORS

Liquid refrigerant must never be allowed to enter the compressor. Liquids are non-compressible, that is, when pressure is applied, their volume remains the same. If liquid refrigerant were allowed to enter the compressor, it would be trapped between the piston and the cylinder head. When the piston attempted to compress it, the total pressure would be applied to the liquid, the piston, the rings, and the cylinder head with the probable breakage of one of these mechanical parts.

In refrigeration systems using high-side floats and capillary tubes, there is a possibility that, at the end of the "on" cycle, liquid refrigerant may leave the evaporator. To prevent its reaching the compressor, a small tank, called an accumulator, is used to collect it (see fig. 19-30). This trapped liquid refrigerant boils off at the beginning of the next "on" cycle.

Another factor to be considered in the design and installation of refrigeration systems is the prevention of oil from the compressor being moved into the rest of the refrigeration system. Oil in the lines and evaporator reduces the efficiency of the system. Because the compressor contains both the refrigerant gas and lubricating oil, it is inevitable that they will mix. Oil separators are used usually between the compressor and the condenser to remove this oil; this is where the refrigerant is a gas and least able to retain the oil. Oil separators contain screens, baffles, and draining facilities to increase the efficiency of separation (fig. 19-31). Figure

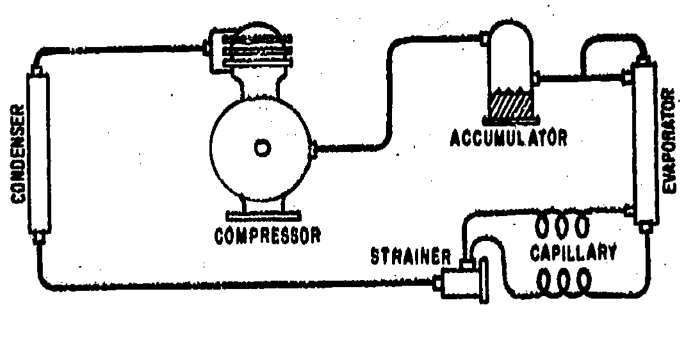


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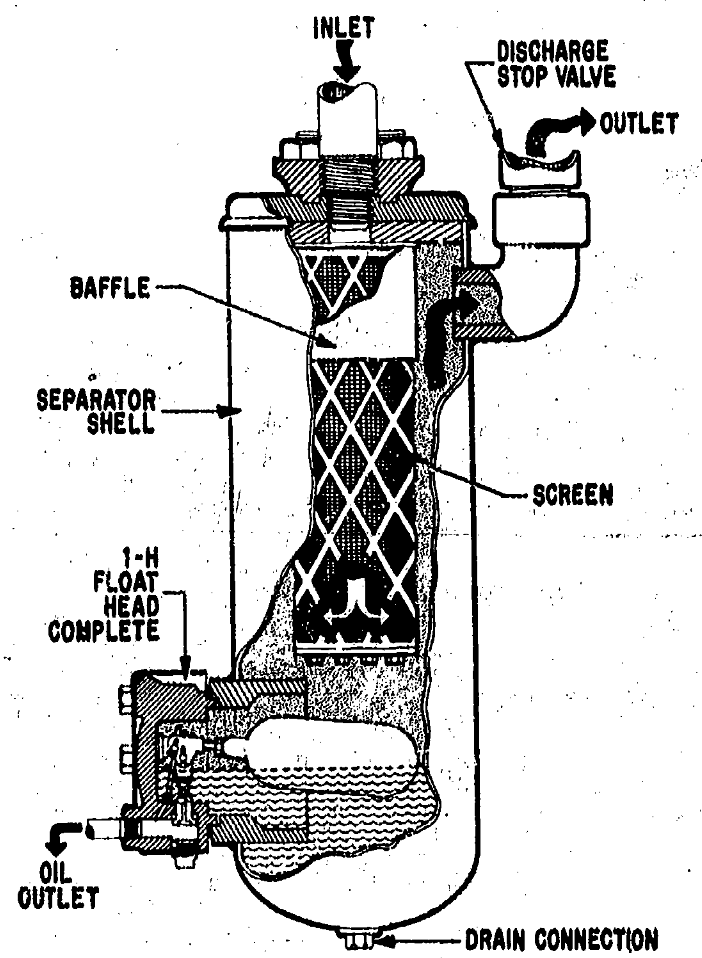
Figure 19-30.—Accumulator location.



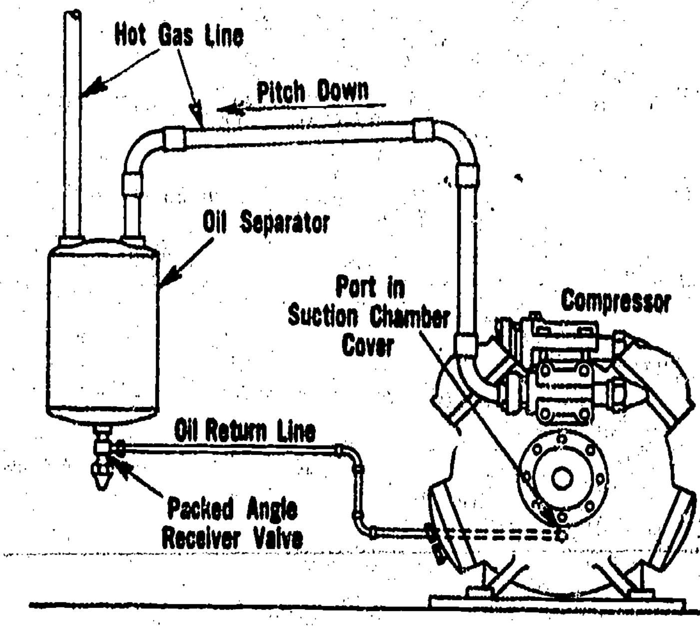
54.338
Figure 19-31.—Cutaway view of an oil separator.

19-32 shows a separator installed in a refrigeration system.

REFRIGERANTS

The refrigerants in common use are fluids and are affected by heat, temperature, and pressure in a manner similar to water. Many different fluids are used as refrigerants, their selection being based on low boiling points and other desirable characteristics. Two common refrigerants used in refrigeration systems are: dichlorodifluoromethane (or R-12), and monochlorodifluoromethane (or R-22).

These are considered as primary refrigerants. This is because each one changes its state upon the application or absorption of heat, and which in this act of change absorbs and extracts heat from an area or substance. The PRIMARY REFRIGERANT is so termed because its action



54.339
Figure 19-32.—Installation of an oil separator.

is direct upon the area or substance, although it may be enclosed within a system.

In order to use a primary refrigerant for cooling purposes, it must be placed in a closed system in which it can be controlled by the pressure imposed upon it. This enables the refrigerant to carry on its absorptive functions at the temperature ranges desired. If a primary refrigerant were used without being controlled, it would absorb heat from most perishables to the extent of freezing them solid.

SECONDARY REFRIGERANTS are substances such as air, water, or brine which in themselves are not refrigerants but have been cooled by the primary refrigeration system, are passed over and around areas and substances to be cooled, and are returned with their heat load to the primary refrigeration system. The use of secondary refrigerants is particularly advantageous where the cooling effect must be transported over a relatively long distance and the use of gas-tight lines is prohibitively expensive.

DICHLORODIFLUOROMETHANE (R-12)

Pure dichlorodifluoromethane (CCl_2F_2) commonly referred to as R-12, is colorless and odorless in concentrations of less than 20 percent by volume in air; in higher concentrations, its odor resembles that of carbon tetrachloride. It has a boiling point of -21.6° F at atmospheric pressure, and at ordinary room temperatures is a liquid when under a pressure of about 70 to 75 psig. R-12 vapor and air mixtures, in all proportions, are nonirritating to the eyes, nose, throat, and lungs. The refrigerant will not contaminate or poison foods or other supplies with which it may come in contact. The vapor is nonpoisonous but will not support respiration and produces mild anesthesia if inhaled in sufficient quantities. In view of the low boiling point at atmospheric pressure, care must be taken to prevent liquid R-12 from coming in contact with the eyes, due to the possibility of freezing. The liquid is nonflammable and nonexplosive, and its air mixtures are not capable of propagating a flame. It is noncorrosive to metals commonly used in refrigerating apparatus.

One hazard which may be introduced through the use of R-12 as a refrigerant is the health hazard which may be presented should leakage of the vapor come into direct contact with an open flame of high temperature (about 1022° F) and be decomposed into phosgene gas, which is highly toxic. However, in order to be a health hazard, the leakage of R-12 must prevail under the following conditions:

1. Large or accumulated leakage in confined space.
2. High temperature flame.
3. Vapor must be brought into direct contact with flame.
4. No ventilation.

If all these conditions exist, the products of decomposition will be pungent and irritating, rendering them noticeable in minute quantities and giving ample warning before concentrations dangerous to health are reached.

R-12 is a stable compound capable of undergoing without decomposition the physical changes to which it is commonly subjected in service. In liquid form, it is an excellent solvent and has the ability of loosening and removing any and all particles such as dirt, scale, or oil, with which it may come in contact within a refrigerating system.

MONOCHLORODIFLUOROMETHANE (R-22)

Monochlorodifluoromethane ($CHClF_2$), commonly called R-22, is a synthetic chemical specially developed for those refrigeration installations that have a very low temperature cooling unit, such as in a fast freezing unit that maintains a temperature of -20° F to -40° F.

The boiling point of R-22 is -41.4° F at atmospheric pressure. This refrigerant is very stable and is nontoxic, noncorrosive, nonirritating, and nonflammable. R-22 when in contact with an open flame will decompose into phosgene gas.

Of the many refrigerants available, R-12 and R-22 are used more than the rest for Seabee-type applications. These two refrigerants will cover the range in temperature from comfort air conditioning to cold storage plants. However, at some locations you may find other primary refrigerants being used, such as ammonia, methyl chloride, or sulfur dioxide.

ADDITIONAL PRIMARY REFRIGERANTS

In addition to R-12 and R-22, other chemicals may be used as refrigerants as long as their boiling point at atmospheric pressure is less than the desired temperature in the evaporator.

Ammonia (NH_3), which is often used as a primary refrigerant, has a boiling point of approximately -28 degrees F at atmospheric pressure and absorbs 5[illegible] Btu's of latent heat per pound of refrigerant at 5 degrees F. However, anhydrous ammonia is extremely dangerous to personnel in that if splashed on the skin or into the eyes it burns by actively seeking water from the areas affected. The first aid procedures include supplying this water by flooding the area.

There are several relatively new refrigerants called azeotropic refrigerants. These are combinations of individual refrigerants and, as such, possess different characteristics than either of their component refrigerants. As one example, R-500, composed of 73.8% R-12 and 26.2% R-152a, has a boiling point of -28 degrees F at atmospheric pressure and absorbs 82.45 Btu's of latent heat per pound of refrigerant at 5 degrees F.

All refrigerants have their own characteristics making it extremely important to charge a system with the refrigerant specified. Use of an incorrect refrigerant can lead to reduced efficiency, mechanical problems, and dangerously unsafe conditions.

SAFETY IN HANDLING REFRIGERANT

In operating refrigerating machines, it is essential that none but the gas for which the particular type of machine is designed to operate be introduced into the system. Introduction of improper gases will, in some cases, result in violent explosions and either completely demolish the machine or render it inoperative.

PERSONAL PROTECTION

Since R-12 is nontoxic, it will not be necessary to wear a gas mask when servicing equipment in which it is contained unless the conditions necessary for decomposition of R-12 exist. However, it is essential that proper protection be afforded the eyes by use of splashproof goggles to eliminate the possibility of liquid refrigerant coming in contact with the eyes, and causing possible injury due to freezing of the moisture in the eyes. This protection is necessary and should be taken whenever loosening a connection in which R-12 liquid may be present.

If liquid R-12 accidentally comes in contact with the eyes, the person suffering the injury should be taken at once to the medical officer. Avoid rubbing or irritating the eyes and give the following first aid treatment immediately.

FIRST. Drops of sterile mineral oil should be introduced into the eyes as an irrigant.

SECOND. The eyes should be washed if irritation continues at all, with one of the following:

a. A weak boric acid solution.
b. A sterile salt solution not to exceed 2 percent salt.

If liquid R-12 comes in contact with the skin, the affected area should be flushed repeatedly with water. Refrigerant saturated clothing should be stripped from the body, the skin washed with water, and the patient taken immediately to the dispensary.

Should a person be overcome in a space which lacks oxygen because of high concentrations of refrigerant being present, such person should be treated in the ordinary manner for people who have experienced suffocation; i.e., through artificial respiration.

Additional information that will assist you in rendering first aid to victims of accidents involving refrigerants is given in the Navy training course, Standard First Aid Training Course, NavPers 10081-B.

HANDLING R-12 CYLINDERS

Never drop cylinders nor permit them to strike each other violently.

Never use a lifting magnet nor a sling (rope or chain) when handling cylinders. A crane may be used when a safe cradle or plateform is provided to hold the cylinders.

Caps provided for valve protection should be kept on cylinders except when cylinders are in use.

Whenever refrigerant is discharged from a cylinder, immediately thereafter weigh the cylinder and record the weight of refrigerant remaining in the cylinder.

Never mix refrigerant gases.

When a cylinder is emptied, immediately close the cylinder valve to prevent entrance of air, moisture, or dirt.

Never use cylinders for rollers, supports, or for any purpose other than to carry gas.

Never tamper with the safety devices in valves or cylinders.

Open cylinder valves slowly. Never use wrenches or tools except those provided or approved by the gas manufacturer.

Make sure that the threads on regulators or other connections are the same as those on cylinder valve outlets. Never force connections that do not fit.

Regulators and pressure gages provided for use with a particular gas must not be used on cylinders containing different gases.

Never attempt to repair or alter cylinders or valves.

STORAGE OF COMPRESSED GAS CYLINDERS

Cylinders may be stored in the open, but in such cases should be protected against extemes of weather. During winter, cylinders stored in the open should be protected against accumulation of ice or snow. In summer, cylinders stored in the open should be screened against continuous direct rays of sunlight.

No part of any cylinder containing compressed gas should ever be subjected to a temperature above 120° F. A direct flame or jet of steam should never be permitted to come in contact with any part of a compressed gas cylinder.

Never store cylinders near highly flammable substances, such as oil, gasoline, or waste.

Cylinders should not be exposed to continuous dampness, salt water, or salt spray.

Store full and empty cylinders apart to avoid confusion.

Do not store full cylinders near elevators or gangways or in locations where heavy moving objects may strike or fall on them.

Protect cylinders from any object that will produce a cut or other abrasion in the surface of the metal.

REFRIGERATING EQUIPMENT

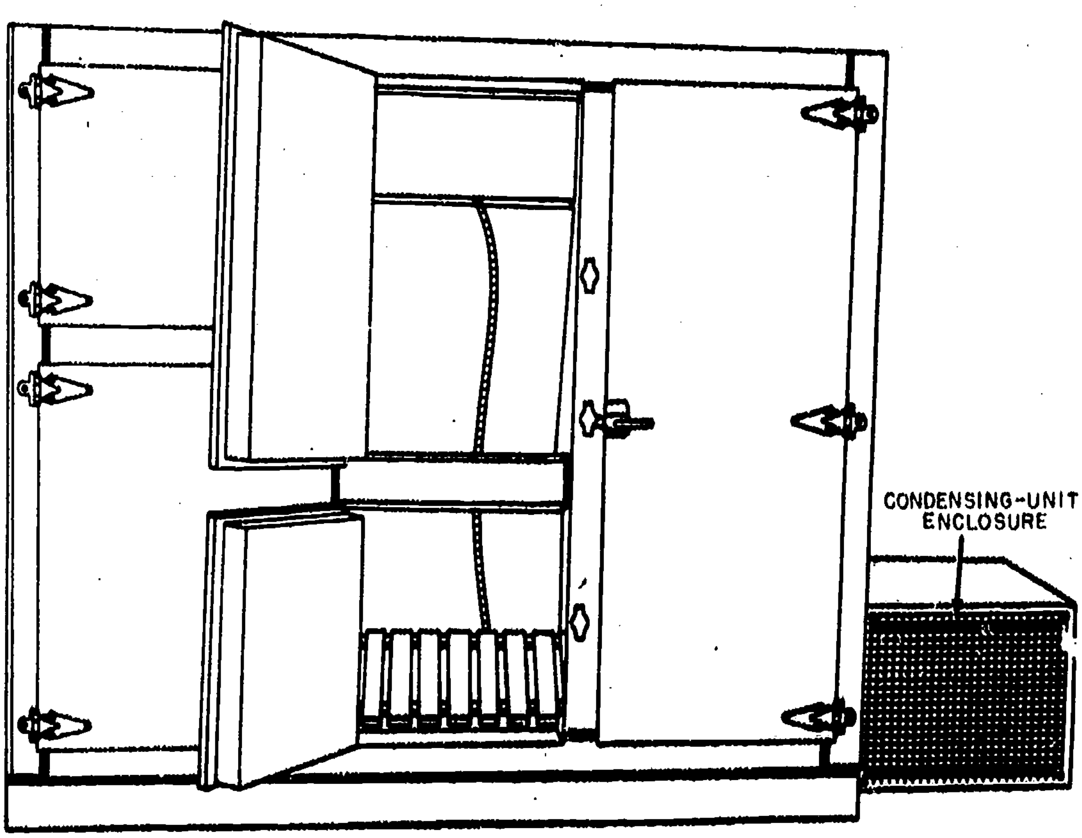
Refrigerating equipment may be grouped in two classifications: the self-contained and the remote types.

With self-contained refrigerating equipment, the cabinet houses both the insulated refrigerating storage compartment in which the evaporator is located, and also the uninsulated compartment in which the condensing unit is located. Such refrigerating equipment may be designed either with a hermetically sealed, a semisealed, or an open condensing unit. In any case, it is completely assembled and charged at the factory, and comes ready for use with little or no installation work. Self-contained refrigerating equipment may include such units as domestic refrigerators, water coolers, reach-in and walk-in refrigerators, small cold storage plants, ice plants, and so on.

Remote refrigerating equipment has the box or cabinet installed in one space while the condensing unit is installed in a remote location. The reason for locating the condensing unit outside of the cabinet may be so that all of the cabinet space may be devoted to the freezer. In addition, the condenser may be so large as to make it impractical to install it in the cabinet. Furthermore, it may be undesirable to allow the heat liberated from the condenser to enter the space around the refrigerator, for example, using a refrigerator in an air conditioned hospital.

REACH-IN REFRIGERATORS

Reach-in refrigerators are similar in design, purpose and general usage to those used in civilian markets and restaurants. They have a storage capacity of 15 cubic feet or more. At Navy installations they are used for the



48.21(54)D

Figure 19-33.—Exterior of reach-in refrigerator with remote condensing unit.

storage of perishable foods in galleys and messes. They are also used in hospitals for the storage of biologicals, serums, and other medical supplies requiring temperatures between 30 degrees and 45 degrees F. Standard-size units most frequently used are those having storage capacities of 15, 20, 30, 45, 65, and 85 cubic feet. The larger sizes are often equipped with a full-height compartment and door, and with rails and hooks for the hanging of large cuts of meat. Observe figure 19-33, which illustrates a typical reach-in refrigerator with detached condensing units.

Exterior finishes for reach-in refrigerators are porcelain-on-steel, lacquered or enameled steel, aluminum, and stainless steel. Interior finishes are usually porcelain-on-steel or wood, such as seasoned gum, fir, or spruce. Shelves are made of plated metal strips, slatted wood, or wire. Insulation is sealed against moisture and is usually board or batt type. Wall thickness averages 4 inches, with 2 inches of insulation where wood exteriors and interiors are used. However, in cabinets located in kitchens, 5-inch walls with 3 inches of insulation are common.

Reach-in refrigerators are usually self-contained units with an air-cooled condensing unit enclosed in an uninsulated compartment, or cabinet. A typical unit is shown in figure 19-34. The wall or panel type of unit cooler is mounted on the rear wall of the food compartment. In operation, warm air is drawn by the fan into the upper part of the unit cooler where it passes over the evaporator coils, is cooled, and then is discharged at the bottom of the cooler. The air then passes up and through the interior and around the contents of the refrigerator. The cycle is completed when the air again enters the evaporator.

Although reach-in refrigerators are normally self-contained systems, in larger refrigerators remote condensing units are sometimes used. Remote-type reach-in refrigerators do not have the condensing unit installed in the refrigerator cabinet. The condensing unit may be located in close proximity to, or at some distance from, the cabinet. Figure 19-35 shows a 65-foot and a 45-foot refrigerator adjacent to each other. Note the air-cooled condensing units mounted one above the other. Usually, open-type compressors are used. However, in small capacity units, the trend has been toward hermetic-type compressors.

Evaporators in reach-in refrigerators are generally the unit cooler type with dry coils.

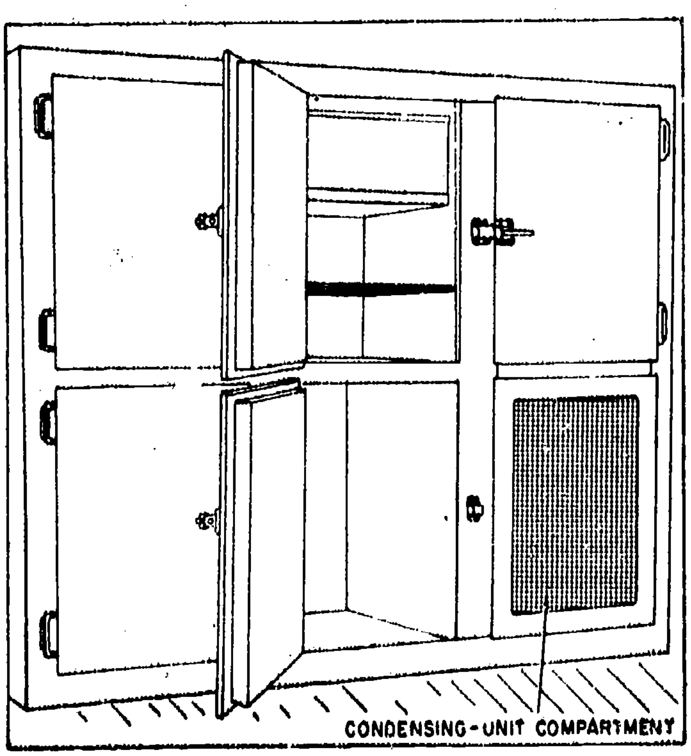


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Figure 19-34.—Self-contained reach-in refrigerator.

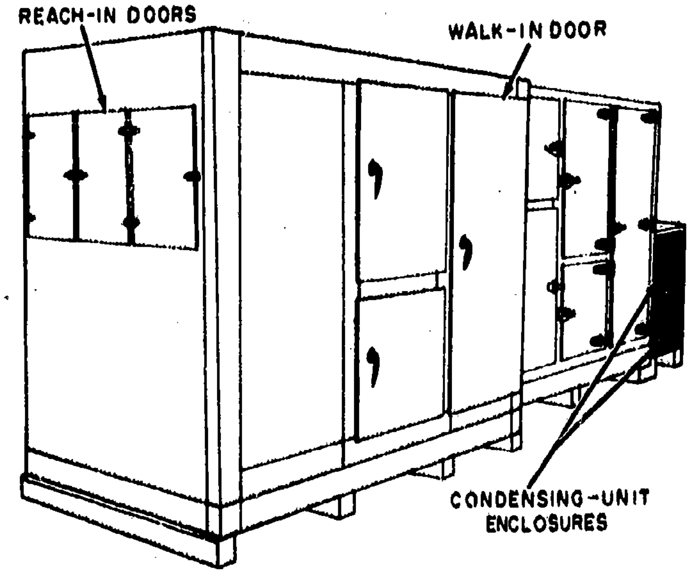

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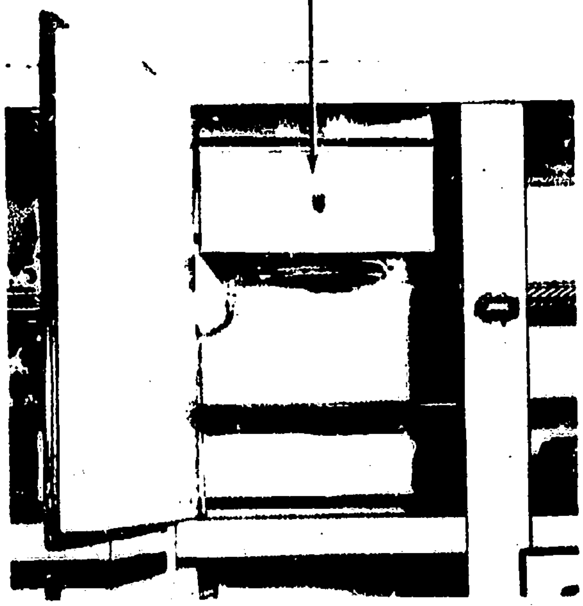
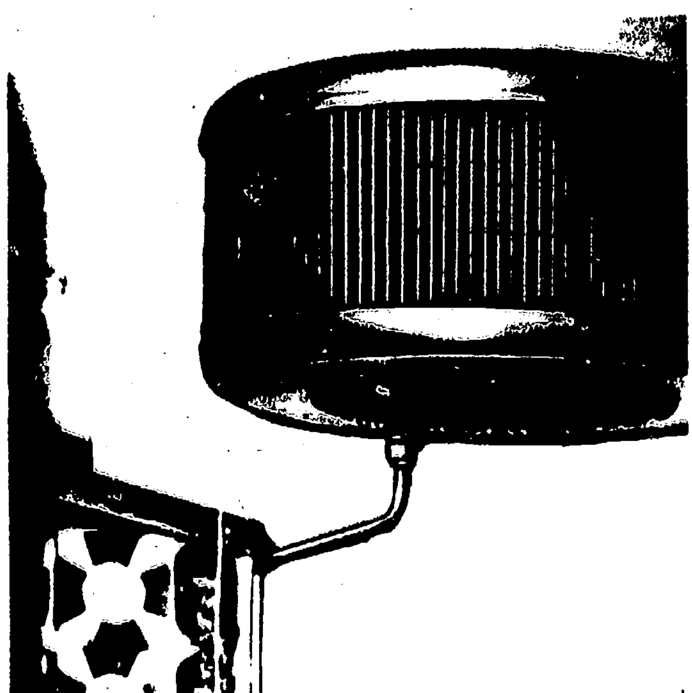
Figure 19-35.—Remote type 65 and 45 cubic foot reach-in refrigerators.



(A)



(B)

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Figure 19-36.—(A) Unit cooler in reach-in refrigerator. (B) Dome cooler in reach-in refrigerator.

Figure 19-37.—Walk-in refrigerator with reach-in door.

(See fig. 19-36.) In smaller capacity refrigerators, ice making coils similar to those used in domestic refrigerators are often used. In addition, straight gravity coils are also found. Refrigerant is normally R-12.

The refrigerant is metered to the evaporator through a thermostatic expansion valve in both remote and self-contained types. The low-pressure control is set to operate the evaporator on a self-defrosting cycle, and temperature is thus controlled. Another type of control system uses both temperature and low-pressure control of special design to control temperature and to effect defrosting on each cycle. The evaporator fan is wired for continuous operation.

WALK-IN REFRIGERATORS

Walk-in refrigerators are normally larger than reach-in types and are described as built-in or prefabricated sectional walk-in units. They are made in two types: one for bulk storage of

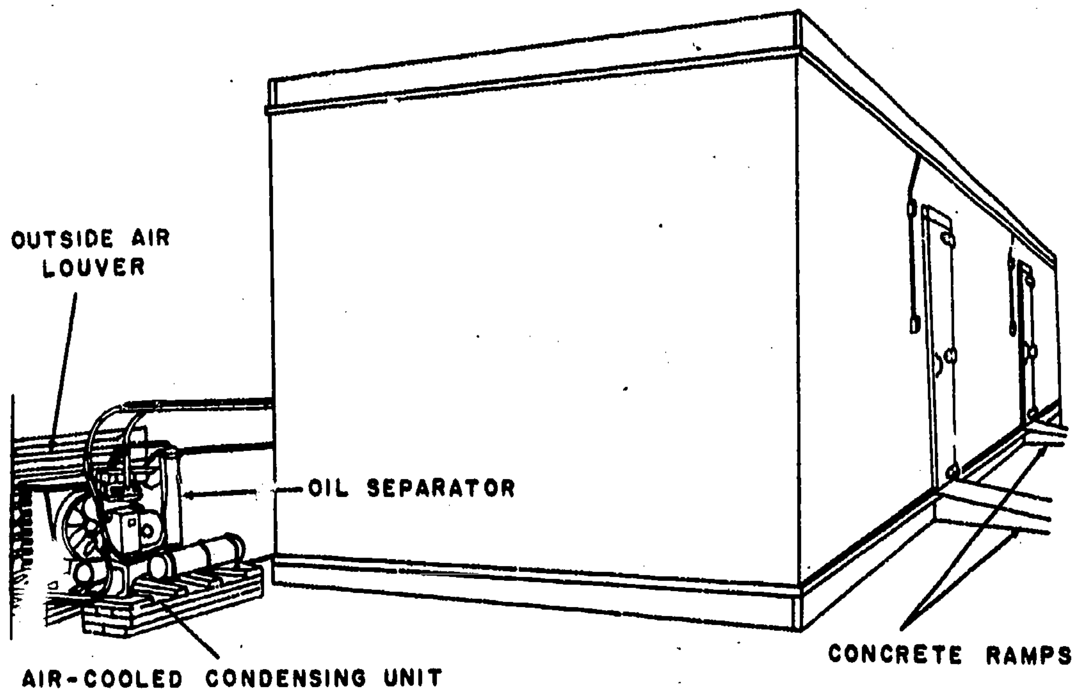

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Figure 19-38. —Walk-in refrigerator for 10 degrees F or below.

fresh meats, dairy products, vegetables, and fruits requiring temperature from 35 to 38 degrees F, and the other for the storage of frozen food at temperatures of 10 degrees F, or below. These 35 to 38 degrees F refrigerators are built and shipped in sections and assembled at the installation. They may be taken apart, moved, and reassembled as required. Larger sizes may have two or three compartments to allow for separation of different types of foods. Standard-size coolers are 4 feet by 6 feet or larger, in floor area. A walk-in refrigerator with reach-in doors is illustrated in figure 19-37.

The exteriors of walk-in refrigerators are of painted or varnished wood, or are metal covered. The interiors are of filled and shellacked or varnished wood. Insulation is made of board or batt, sealed against moisture. For storage temperatures between 35 degrees and 40 degrees F, 3 or 4 inches of insulation are generally used. For low-temperature application, such as the storage of frozen foods, 5 or more inches of insulation are used. These refrigerators are equipped with meat racks and hooks for the storage of meat in carcass form. Small-size walk-in refrigerators have shelves as well as racks. The compressor and condenser units are located outside of the main structure. The walk-in type designed for 10 degrees F or below (see fig. 19-38) is similar to the 35 to 38 degrees F type, except that insulation is usually about one and one-half times thicker, and that meat hooks or rails are not provided, because frozen food is usually stacked on dunnage.

The operation of walk-in refrigerators is similar to that of reach-in units. The evaporator must have sufficient capacity (Btu per hour) to handle the heat load from infiltration and product load. The condenser is sized to handle the evaporator Btu per hour plus the heat added by the compressor. In the field it will be noted that the condensing units are rated by their capacity to remove heat during a 1-hour period. Evaporators are made in several forms; their selection depends on the conditions under which they are to operate. Both gravity-type and forced-air evaporators are used, and normally there is little difference in the results obtained. The operation of the forced-air evaporator is normally a continuous cycle. Warm air in the refrigerator box is drawn into the fan and forced over the evaporator coils where it is cooled, and is blown back into the box when the fan is operating. Occasionally, maintenance personnel may be confronted with the complaint that stored products in a refrigerator are being dehydrated

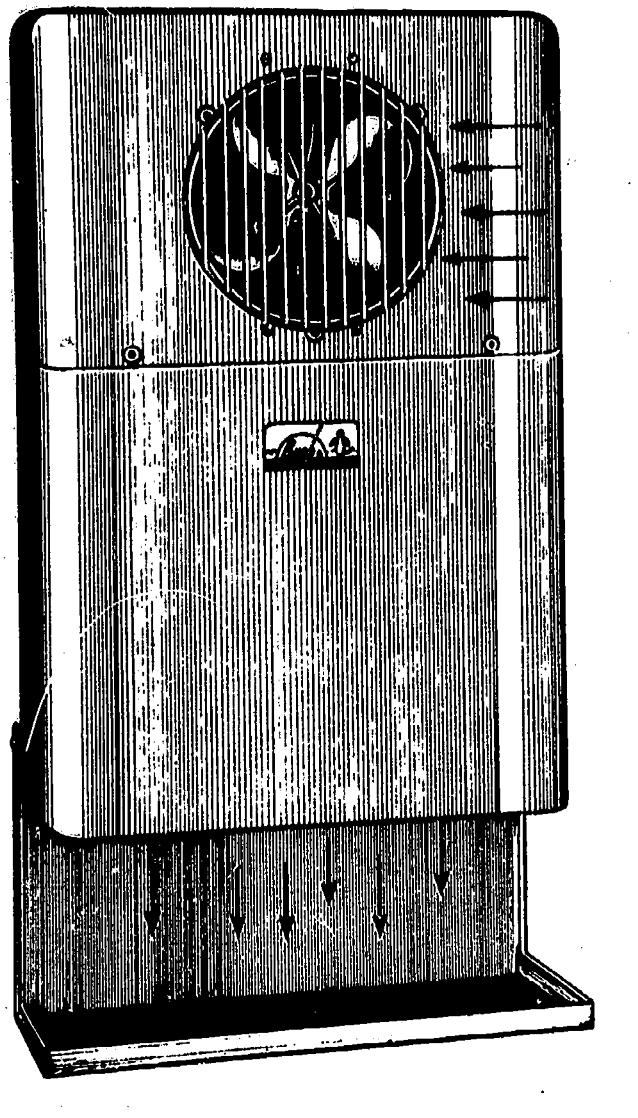

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Figure 19-39.—Wall-mounted panel-type evaporator.

or dried out. It must be remembered that forced-air evaporators can cause dehydration because of the product being stored in a high-velocity zone. Gravity coils, on the other hand, do not have this disadvantage.

The condensing unit is generally located outside of the main structure. These are equipped with either air-cooled or water-cooled condensers. The warm air coming off the condenser is blown outside of the building through air louvers.

Evaporators used in walk-in refrigerators may be the wall type with forced-air blowers, or they may be the plate type. Circulation of cooling air is required in refrigerators of this type to maintain a fairly constant temperature throughout the storage area. The warm air from the cold storage compartment is drawn in by the fan at the top of the evaporator. The air is cooled as it passes around the evaporator coils. The cool air is then discharged at the bottom of the evaporator. Figure 19-39 illustrates a wall-mounted evaporator. Plate-type evaporators are illustrated in figure 19-40. These types are hung in banks, after being fabricated and assembled complete with a thermostatic-expansion valve and a heat exchanger. Circulation of air around the evaporators is accomplished by natural convection drafts.

A thermostatic control is located inside the cold storage room for temperature control. A solenoid valve in the liquid line of the compressor is opened and closed by the thermostatic control. A suction-pressure switch controls operation of the compressor. A high-pressure cut-out switch is sometimes provided.

INSTALLATION OF REFRIGERATING EQUIPMENT AND UNITS

As a UT 3 or 2, you will be called upon to help with the installation of refrigeration systems. Even though you will usually follow plans and work under supervision, you need to be aware of some of the basic requirements applicable to all installations.

It is of major importance that extreme care be taken in the installation of a refrigerating or air-conditioning plant to take measures to prevent the admittance of any foreign matter such as dirt, scale, sand or moisture into any portion of the refrigerant system. Since air contains moisture, its entrance to the circuit should be controlled as much as possible during installation. A great majority of maintenance problems may be traced to lack of proper precautions during erection and installation. It is important that all openings to the refrigerant circuit, piping, controls, compressors, condensers, and so on, be adequately sealed during the times when work on them is not actually in progress. The R-12 refrigerant is a powerful solvent which will readily dissolve all foreign matter and moisture which may have entered the system during installation. This material is soon carried to operating valves and compressor and becomes a distinct menace to bearings, pistons, cylinder walls, valves, and the lubricating oil. Scoring of moving parts frequently occurs when the equipment is first operated,

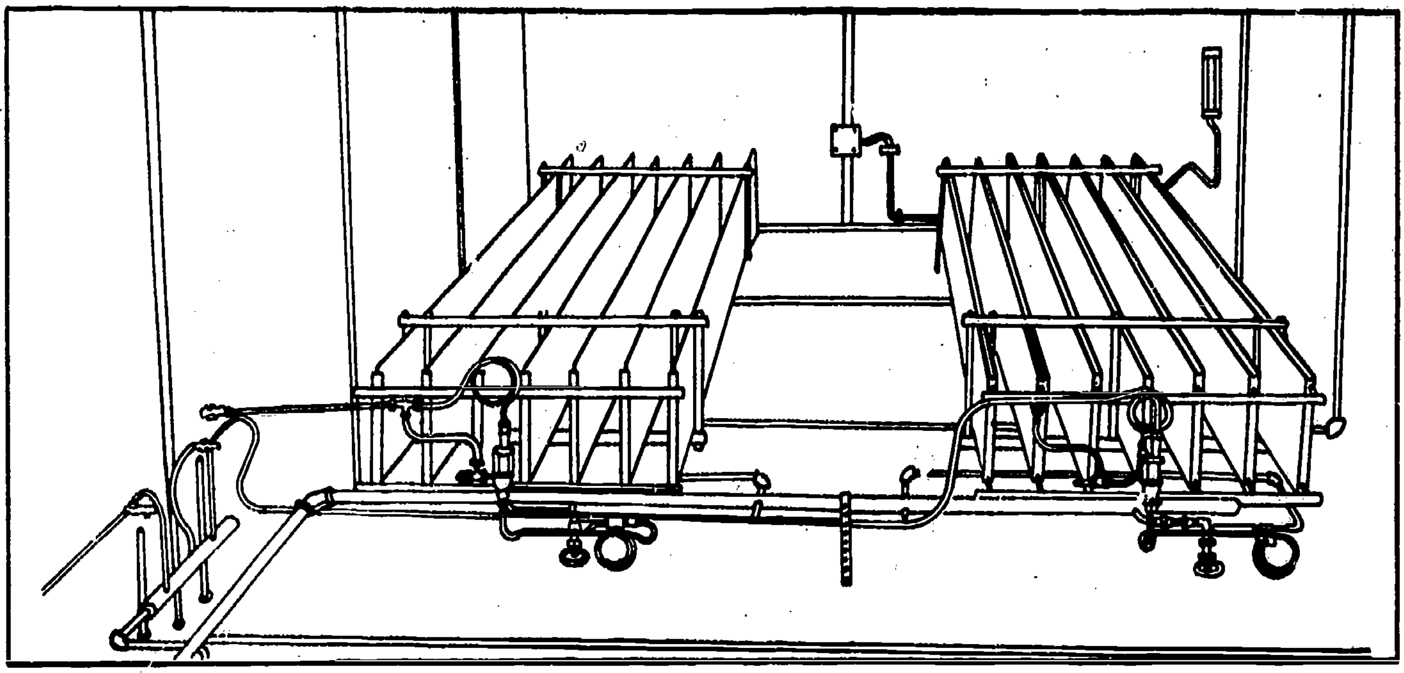

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Figure 19-40.—Plate-type evaporators.

starting with minor scratches which progressively increase until the operation of the compressor is seriously affected.

Copper tubing and copper piping used for installation and in accordance with existing specifications should be cleaned, deoxidized, and sealed. When there is a question about cleanliness of tubing or piping to be used, each length of pipe should be thoroughly blown out with a strong blast of dry air and cleaned with a cloth swab attached to copper wire pulled back and forth in the tube until it is clean and shiny. Then the ends of the tubes should be sealed until such time as actual connection to the rest of the system is made.

EFFECTS OF MOISTURE

Moisture in as small a quantity as 15 to 20 parts of moisture per million parts of R-12 can cause severe corrosion in a system. The corrosion is a result of hydrochloric acid formed by the R-12 when in contact with water. A chemical reaction takes place between the acid and the iron and copper in the system, to form corrosion products. A strong acid in conjunction with the high discharge and compressor temperature can cause decomposition of lubricating oil to produce a sludge of breakdown products. Either the corrosion or oil breakdown products can plug valves, strainers, and driers and cause a serious casualty.

The formation of ice in expansion valves and capillary tubes can occur when operating below 32° with a relatively minute quantity of moisture.

LOCATION OF EQUIPMENT

Adequate space should always be left around the major portions of equipment which may require servicing, otherwise the equipment may of necessity have to be moved after installation in order that serviceable parts may be accessible. Compressors require overhead clearance for removal of head, discharge valve plate, and pistons, with side clearance to permit removal of fly wheel and crankshaft where necessary. Water-cooled condensers require free area equivalent to the length of the condenser at one end to provide room for cleaning tubes, installation of new tubes, or removal of the condenser tube assembly. Consideration should be given to the space requirements for servicing valves and accessory equipment. Service openings and inspection panels on unitary equipment require generally at least 18 inches clearance for removal of the panel. It is essential that air-cooled condensing units be located so as to permit unrestricted flow of the air required for condensing, whether the condenser is located in a unitary piece of equipment or separately located.

VENTILATION

Adequate ventilation should be supplied to all air-cooled condensing units, otherwise overloading of the motor and loss of capacity will result.

REFRIGERANT PIPING—GENERAL PRECAUTIONS

Certain general precautions for the installation of refrigerant lines should be followed. When the receiver is located above the cooling coil, the liquid line should be carried up at least 6 feet before going down to the evaporator. This inverted loop prevents siphoning of the liquid from the receiver over into the cooling coil through an open or leaking expansion valve during compressor shut-down period. If siphoning starts, the liquid refrigerant will flash into a gas at the top of the loop, thus breaking the continuity of the liquid column and stopping the siphoning action. Where the cooling coils and compressors are located on the same level, it is recommended that both the suction and liquid lines be run to the overhead and then down to the condensing unit, pitching the suction line toward the compressor to facilitate oil return. On close-coupled installations, the running of both lines up to the overhead helps to eliminate vibration strains as well as give the necessary trap at the cooling coil.

INSTALLATION OF REFRIGERANT PIPING

Preparation of the pipe and fittings for installation is of utmost importance. Care must be exercised in the cutting of copper tubing or pipe to prevent the filings or cuttings from entering the pipe. The small particles of copper should be completely removed since the finely divided copper may pass through the suction strainer. The tube should be cut square and all burrs and dents should be removed in order that no internal restrictions are introduced and to permit proper fit with companion fittings. If cutting is accomplished by means of a hacksaw, a fine-tooth blade should be used, preferably 32 teeth per inch.

When making silver soldered joints, it is necessary to brighten up the ends of the tubing or pipe with a wire brush or crocus cloth to make a good bond. Do not use sandpaper, emery cloth, or steel wool for this cleansing, as this material will get into the system and may become a direct cause of trouble.

Under no consideration should acid be used for soldering and the flux used must be a type whose residual substance will not form an acid. Use flux sparingly so that no residue will get inside of the system which would eventually be washed back to the compressor crank case. The danger of admittance of excessive flux as well as solder and brazing material is more accentuated where fittings and tubing are improperly fitted through distortion in preparation.

The temperature required for soldered or brazed joints will cause oxidation within the tubing and eventually will be removed by the R-12 flow after the system is in operation. The oxide will break up into a fine powder to contaminate the lubricant in the compressor and to plug strainers and driers. In order to eliminate this possibility, a neutral atmosphere should be provided within the tube being soldered or brazed. This can be accomplished by the use of oil-pumped nitrogen, gas-bled through the tubing during the soldering or brazing operation and for a sufficient time after the bond is made, until the heat of the copper has been reduced below the temperature of oxidation. This method is also recommended for repair of a leak after the system has been charged with R-12, to blow out any traces of the refrigerant vapor and oil to prevent the break-down of any refrigerant which may create harmful acid or permit contamination of the system. Carbon dioxide may be substituted when nitrogen is not available.

All joints used should be silver-soldered and the joints be kept to an absolute minimum to reduce the possibility of leaks. Special copper tube fittings designed for refrigeration service should be used, since these are manufactured with close tolerances to assure tight capillary joints in the brazing process. SAE flare joints are generally not desired but where necessary, care should be taken in making the joint. The flare must be of a uniform thickness presenting a smooth, accurate surface free from tool marks, splits, or scratches. The tubing must be cut square, provided with a full flare, and any burrs and saw filings should be removed. The flare seat of the fitting connector must be free from dents or scratches. The flare can best be made by use of a special swivel head flaring tool available as a general stores item which remains stationary and does not tear or scare the face of the flare in the tubing. Oil should not be used on the face of the flare either in making up the flare or in securing it to the fitting since the oil will eventually be dissolved by the refrigerant in the system, causing a leak through the displacement of the oil. The flare joint should always be tightened with the use of two wrenches—one to turn the nut and the other to hold the connecting piece to prevent the possibility of applying strain on the connection which may result in a leak.

Where bending of pipe or tubing is necessary, bends should be made by the use of special tools designed for this class of work. The use of rosin, sand, or any other type of filler inside of the tubing in order to make a bend is not recommended. Threaded joints should be sealed with special refrigerant pipe dope. Where it is necessary, as an emergency measure, to use a thread compound for making up a joint, it must be kept in mind that R-12 is a hydrocarbon which will dissolve any compounds containing oil. A compound containing an acid or one whose residual substance will form an acid should not be used. The use of a thin paste made of fresh litharge and glycerine will make a satisfactory joint compound; however, the joint should be thoroughly cleaned with a solvent to eliminate any oil or grease. Thread compound should be applied to the male part of the thread after the male piece has entered one and a half to two threads to prevent any excess compound from entering the system.

When securing, anchoring, or hanging the suction and liquid lines, care must be exercised to permit sufficient flexibility between the compressor and the first set of hangers or points at which the lines are secured, to permit a certain amount of freedom and relieve any possible strain in the joints of

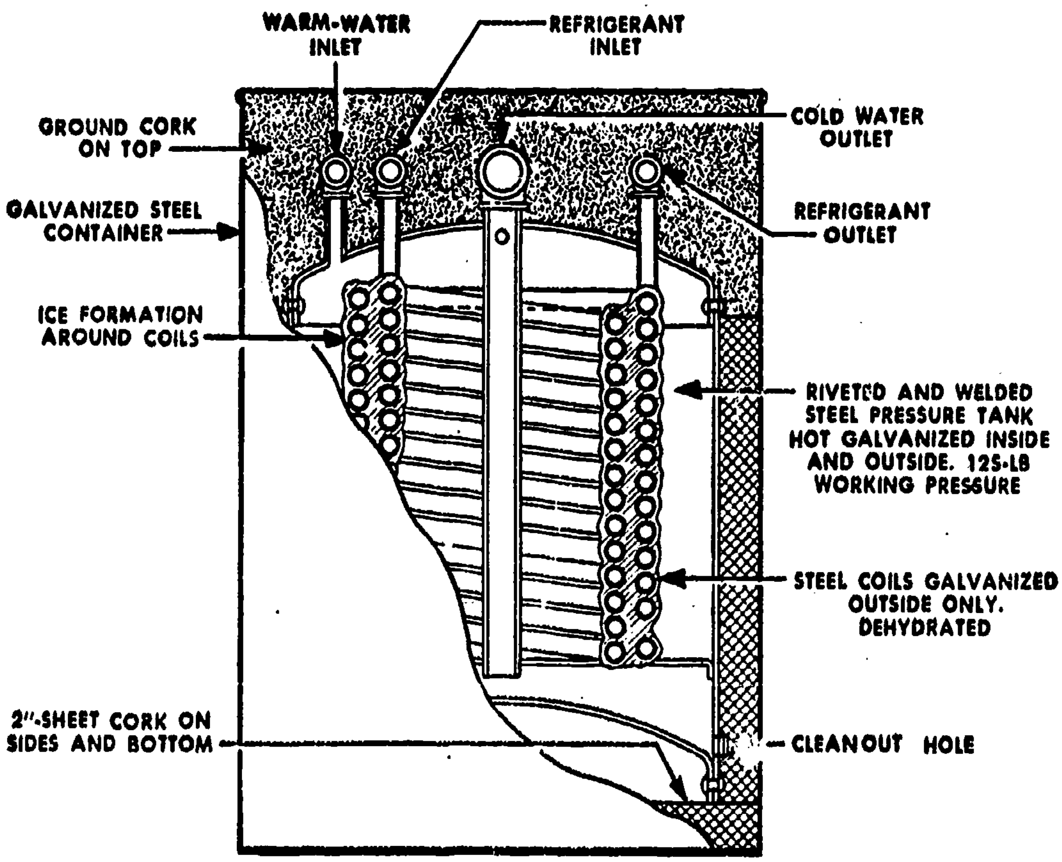

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Figure 19-41.—Storage-type water cooler.

these lines at the compressor due to compressor vibration.

OTHER REFRIGERATING EQUIPMENT

Other types of refrigerating equipment which you may find at your activity—in addition to the refrigerators discussed above—include ice making machines which produce either flake ice or ice cubes. These are self-contained, automatic machines which continuously produce ice until the built-in storage bin is full. The primary difference in the design of these machines and that of refrigerators lies in the use of the evaporator. In some machines, water is sprayed onto the evaporator where it freezes and is scraped off to form flake ice. In other machines, molds (similar to ice cube trays) are used in the evaporator to freeze water into cubes. At the end of the freezing cycle, the molds are heated and the cubes dumped into the storage bin.

A very desirable piece of equipment at any Seabee activity is the ICE CREAM PLANT. Two sizes are currently available. One has a 6-quart freezing unit, which has a hardening and dispensing capacity of 20 gallons. The other has a 20-quart freezing plant with a hardening and dispensing capacity of 80 gallons. Both are self-contained skid mounted units. Each plant is electrically powered.

Ice-cream DISPENSING CABINETS, likewise, are available. The cabinets are equipped with steel cans to afford storage of either 30, 35, or 40 gallons of ice cream. They are electrically operated and have a corrosion-resistant top, lids, and hardware.

Bottled and canned beverage coolers used in the Navy are similar to the type commonly found in grocery stores and other commercial establishments. According to size, these coolers hold approximately 528 or 768 bottles of 12-oz size. The coolers have corrosion-resistant hardware, removable wire compartment dividers, apron, and covers.

A very common device used in many areas is the water cooler. It is designed to supply water at a temperature under 50 degrees F. Most water coolers are self-contained, with the condensing unit in the lowest part of the cabinet. Water coolers are of two general types—instantaneous and storage. The instantaneous type cools water only when and as it is drawn for use; the storage type maintains a reservoir of cooled water. The principles of operation are the same as for refrigerators—only the design of the evaporator varies. One instantaneous method used is to place coils through which the water flows in a flooded evaporator. A second instantaneous method is to use double coils with water flowing through the inner coil and refrigerant flowing in the space between the inner coil and outer coil. A third method is to coil the tubing in a water storage tank and allow refrigerant to flow through it (see figure 19-41).

We might note that still other common types of refrigerating equipment include domestic refrigerators and home freezers. These units are discussed later in this chapter, so detailed information is not given on them at this point.

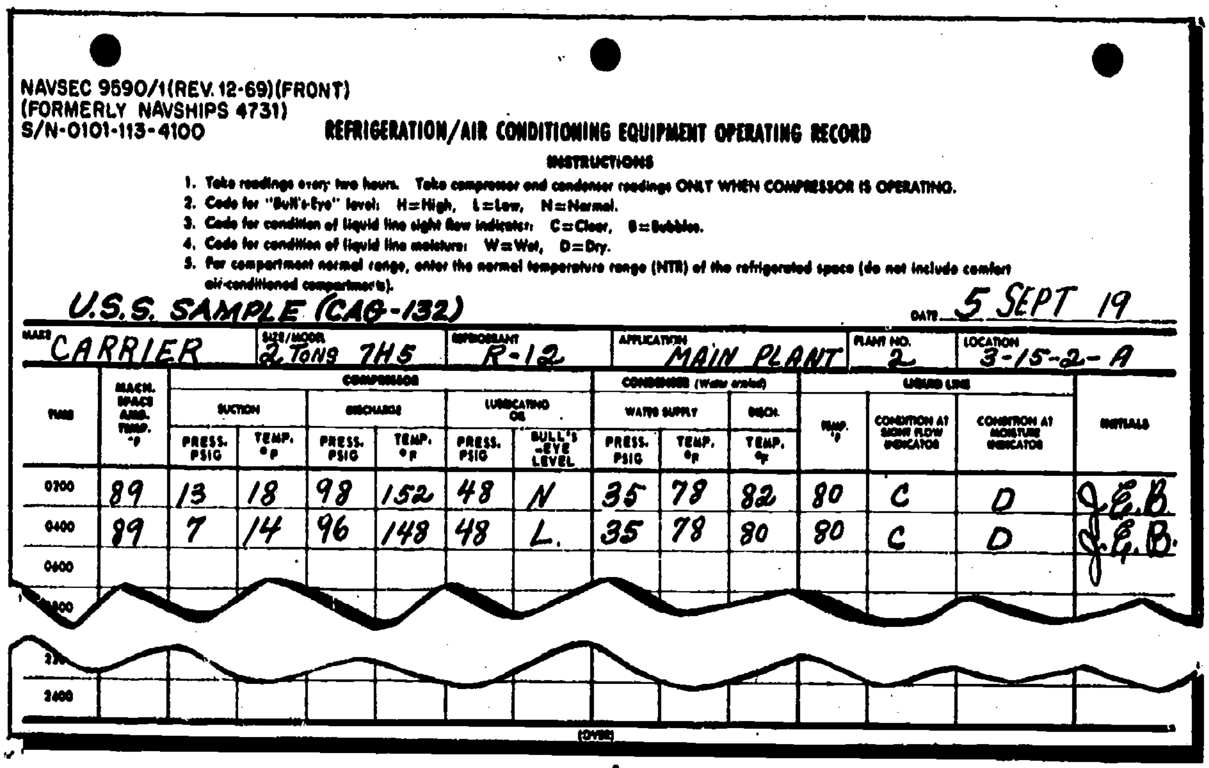
LOGS

In operating or standing watch on refrigerating or air-conditioning equipment, the UT may be responsible for keeping a daily operating log on the equipment. A special effort should be made to keep the logs neat and clean. Make sure, also, that information recorded on them is accurate, as well as legible.

Operating logs may be beneficial in spotting trouble in the equipment. They are also useful in programming and scheduling of maintenance work. In addition, operating logs may provide a means of self-protection in case trouble occurs where the cause can be placed on the individual.

Good judgement must always be used in the analysis of service troubles and specific corrections should be followed wherever possible. One of the best methods for determining when and what corrective measures are necessary for a plant which is not operating properly is by comparing the pressures and temperatures existing at various parts of the system with corresponding readings taken in the past when the plant is known to be operating properly and under similar heat load and circulating water temperature conditions.

A typical daily operating log (NavSec 9590/1) for refrigerating equipment is shown in figure 19-42. The information recorded in this type of operating log may be used as a guide for a continuing analysis of the operating conditions and operating results found in a refrigeration or air-conditioning plant. The columns "Mach. space amb. temp. °F" and "water supply" are influencing conditions, a record of which is desirable for comparative results. Other columns represent operating results. Where improper results are evidenced, an immediate check should be made to determine the cause and remedy. Such precaution may avert serious derangement. For



NAVSEC 9590/1(REV. 12-69)(FRONT)
(FORMERLY NAVSHIPS 4731)
S/N-0101-113-4100

REFRIGERATION/AIR CONDITIONING EQUIPMENT OPERATING RECORD

INSTRUCTIONS

1. Take readings every two hours. Take compressor and condenser readings ONLY WHEN COMPRESSOR IS OPERATING.
2. Code for "Bull's-Eye" level: H=High, L=Low, N=Normal.
3. Code for condition of liquid line sight flow indicator: C=Clear, B=Bubbles.
4. Code for condition of liquid line moisture: W=Wet, D=Dry.
5. For compartment normal range, enter the normal temperature range (NTR) of the refrigerated space (do not include comfort air-conditioned compartments).

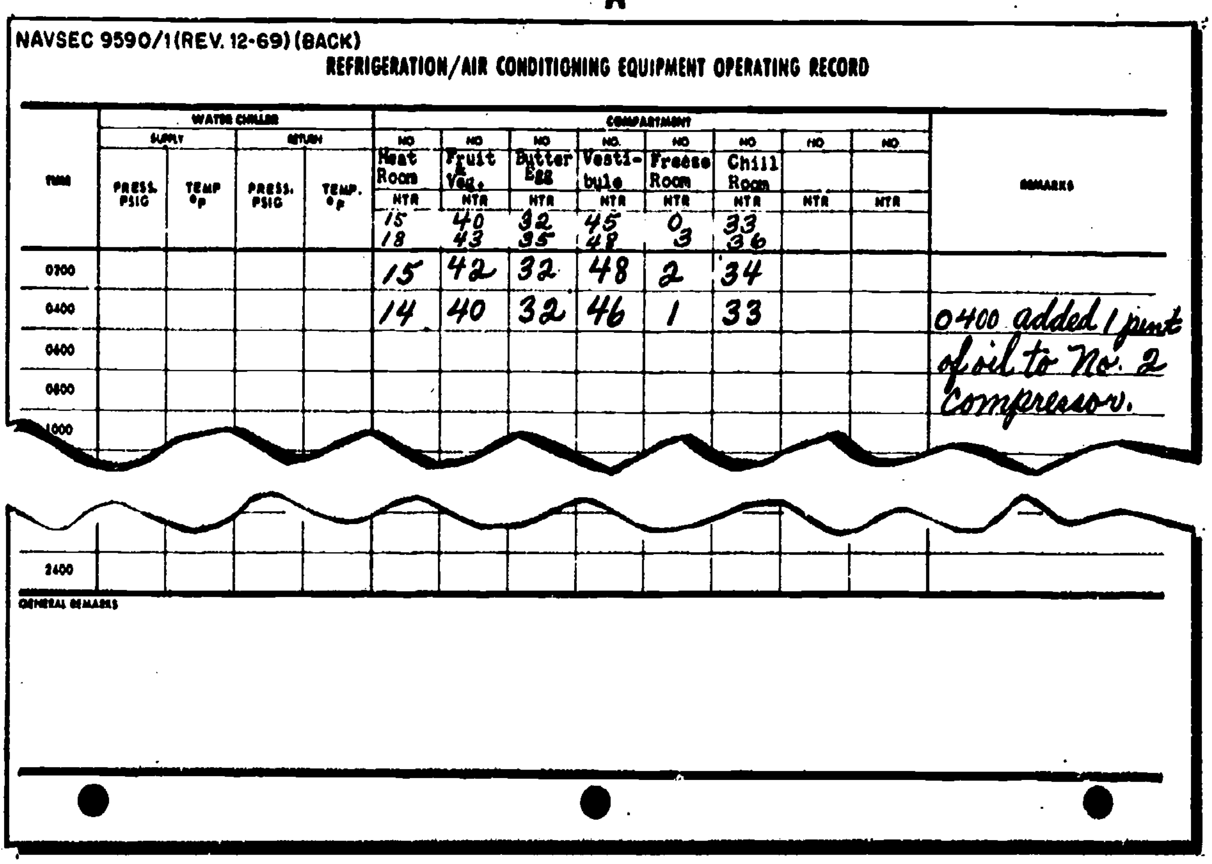
U.S.S. SAMPLE (CAG-132) DATE 5 SEPT 19

MAKE CARRIER | SIZE/MODEL 2 TONS 7H5 | REFRIGERANT R-12 | APPLICATION MAIN PLANT | PLANT NO. 2 | LOCATION 3-15-2-A

TIME	MACH. SPACE AMB. TEMP. °F	COMPRESSOR SUCTION PRESS. PSIG	COMPRESSOR SUCTION TEMP. °F	COMPRESSOR DISCHARGE PRESS. PSIG	COMPRESSOR DISCHARGE TEMP. °F	COMPRESSOR LUBRICATING OIL PRESS. PSIG	COMPRESSOR LUBRICATING OIL BULL'S-EYE LEVEL	CONDENSER (Water cooled) WATER SUPPLY PRESS. PSIG	CONDENSER (Water cooled) WATER SUPPLY TEMP. °F	CONDENSER (Water cooled) DISCH. TEMP. °F	LIQUID LINE TEMP. °F	LIQUID LINE CONDITION AT SIGHT FLOW INDICATOR	LIQUID LINE CONDITION AT MOISTURE INDICATOR	INITIALS
0200	89	13	18	98	152	48	N	35	78	82	80	C	D	J.E.B.
0400	89	7	14	96	148	48	L.	35	78	80	80	C	D	J.E.B.
0600														
0800														
2400														

(OVER)

A



NAVSEC 9590/1(REV. 12-69)(BACK)

REFRIGERATION/AIR CONDITIONING EQUIPMENT OPERATING RECORD

TIME	WATER CHILLER SUPPLY PRESS. PSIG	WATER CHILLER SUPPLY TEMP °F	WATER CHILLER RETURN PRESS. PSIG	WATER CHILLER RETURN TEMP. °F	COMPARTMENT NO. Heat Room NTR 15-18	COMPARTMENT NO. Fruit & Veg. NTR 40-43	COMPARTMENT NO. Butter Egg NTR 32-35	COMPARTMENT NO. Vesti-bule NTR 45-48	COMPARTMENT NO. Freeze Room NTR 0-3	COMPARTMENT NO. Chill Room NTR 33-36	COMPARTMENT NO. NTR	COMPARTMENT NO. NTR	REMARKS
0200					15	42	32	48	2	34			
0400					14	40	32	46	1	33			0400 added 1 pint of oil to No. 2 compressor.
0600													
0800													
1000													
2400													

GENERAL REMARKS

B

47.104

Figure 19-42.—Refrigeration/Air Conditioning Equipment Operating Record, NavSec 9590/1. (A) Front. (B) Back.

example, if the actual suction temperature drops to the temperature corresponding to the existing suction pressure as indicated by the temperature and pressure scales on the suction pressure gage, the return of liquid is definitely indicated. Further evidence of liquid slop-over will be indicated by a drop in compressor discharge temperature. If liquid does return to the compressor, the trouble must be corrected at once, to prevent possible damage to the compressor.

MAINTENANCE, SERVICING AND REPAIR OF REFRIGERATING EQUIPMENT

As a UT, you must be able to perform various duties concerned with the maintenance, servicing and repair of refrigerating equipment. This phase of our discussion provides information on different jobs that you may be called upon to handle. When information here varies from that contained in the latest Federal or Military Specifications, the Specifications shall apply. You will find the "Troubleshooting Checklist—Refrigeration Systems," which is presented in table 19-3 in this chapter, a great help in locating and correcting troubles. Manufacturers also provide instruction manuals which will be useful to you in maintaining and servicing their equipment.

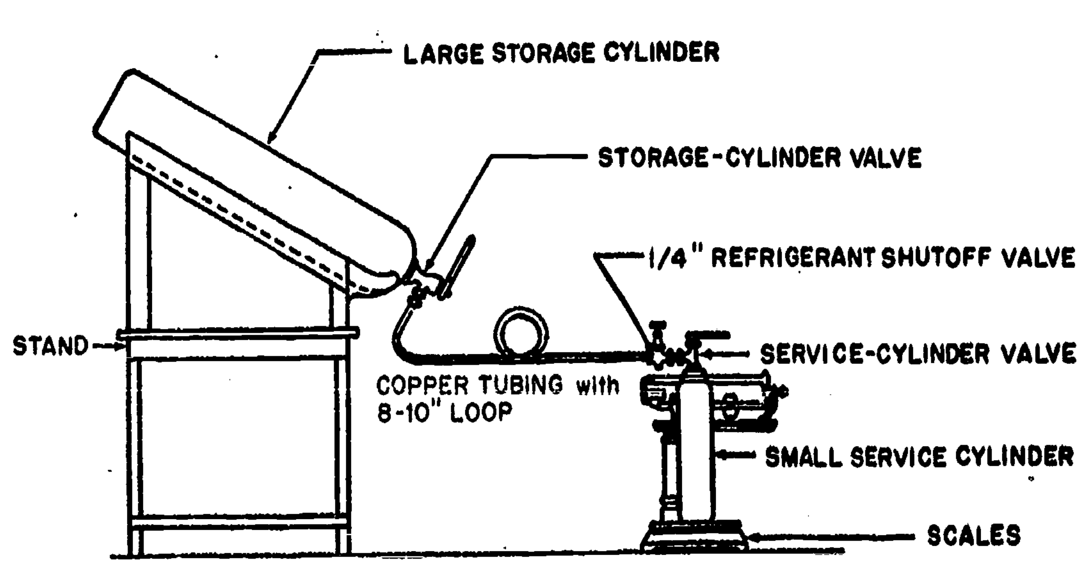
TRANSFERRING REFRIGERANTS

Refrigerants are shipped in compressed gas cylinders as a liquid under pressure. Liquids are usually removed from the shipping container and transferred to a service cylinder.

Before attempting transfer of refrigerant from a container to a cylinder, precool the receiving cylinder until its pressure is lower than that of the storage container or cylinder. Precooling may be accomplished by placing the cylinder in ice water or a refrigerated tank. You must also weigh the service cylinder, including cap, and compare it with the tare weight stamped or tagged on the cylinder. The amount of refrigerant that can be placed in a cylinder is 85% of the tare weight (the weight of a full cylinder and its cap minus the weight of the empty cylinder and its cap). The tare capacity of standard Navy R-12 cylinders may be ascertained from the following:

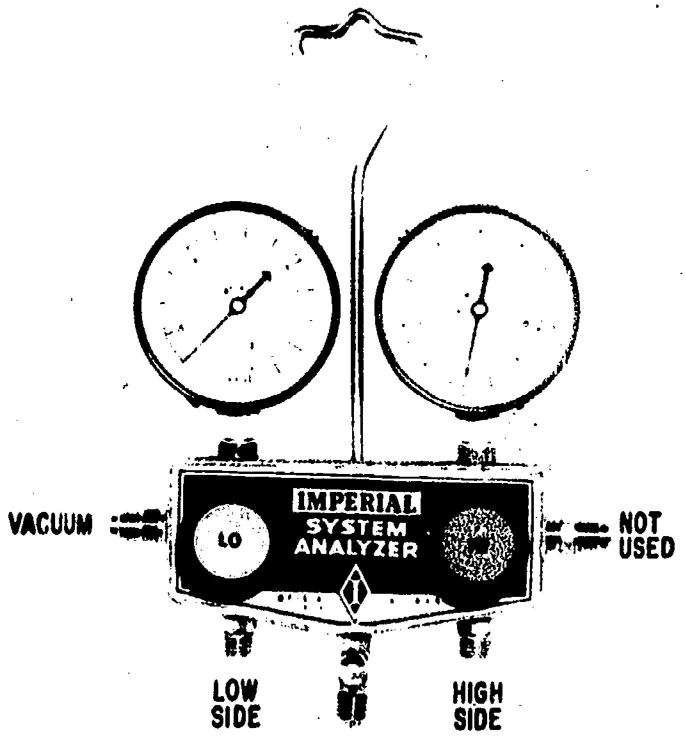
Capacity of cylinder	Diameter	Length of cylinder body
	Inches	Inches
50 pounds	8-1/4	26-3/4
10 pounds	4-3/16	25-1/4

Connect a flexible charging line on 1/4-inch copper tube several feet long with a circular loop about 8 to 10 inches in diameter. Be sure to install a 1/4-inch refrigerant shutoff valve (see fig. 19-43) in the charging line to the service cylinder. This valve should be inserted so no more than 3 inches of tubing are between the last fitting and the valve itself. This arrangement prevents the loss of

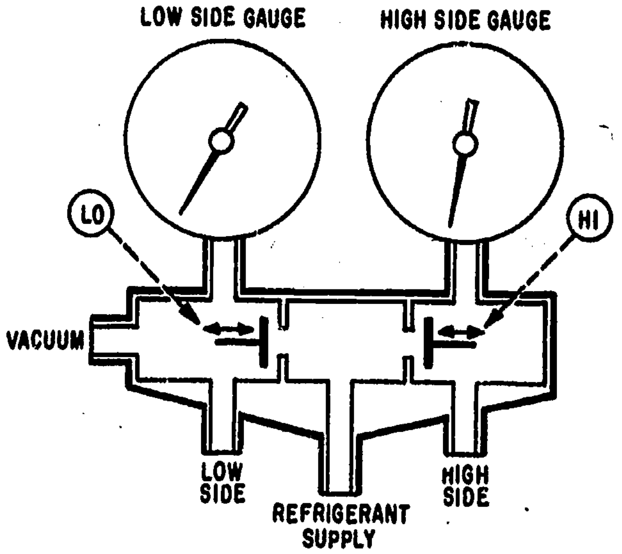


54.167

Figure 19-43.—Method of transferring refrigerants to service cylinders.



54.341
Figure 19-44. — Refrigerant manifold test set.



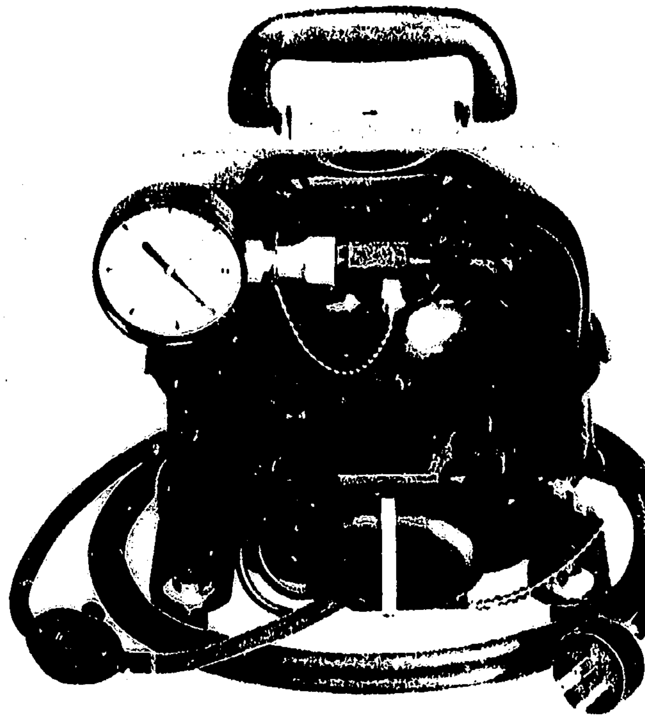
54.342
Figure 19-45. — Internal view of refrigerant manifold test set.

refrigerant when the service drum is finally disconnected. The entire line must be purged (cleared) of air by leaving the flare nut on the service cylinder loose and cracking the storage cylinder valve. This will allow refrigerant to flow through the tubing, purging it. After purging, tighten the flare nut and then open the valve on the service cylinder, the valve on the storage cylinder, and then the 1/4-inch valve in the refrigerant line. When the weight of the service cylinder indicates a sufficient amount of refrigerant is in the service cylinder, close all valves tightly, and disconnect the charging line at the service cylinder.

Should it become necessary to warm refrigerant containers or cylinders to promote more rapid discharge, extreme care should be taken to prevent a temperature above 120° F as the fusible plugs in the cylinder and valve have a melting point of about 157° F and soften at a lower temperature.

TYPICAL REFRIGERATION SERVICING EQUIPMENT

Repair and service work on refrigeration systems involves two major considerations — containing the refrigerant and accurately measuring pressures. One piece of equipment designed to accomplish this is the refrigerant manifold test set (fig. 19-44). It consists of a 0-500 psig gage for measuring pressure at the compressor high side, a compound gage (0-250 psig and 0 to -30 inches of mercury) to measure the low or suction side, valves to control admission of these pressures to the gages, and the connections and lines required to connect the test set to the system. Depending on test and service requirements, the test set can be connected to the low side, the high side, a source of vacuum, or a refrigerant cylinder. A swiveling hanger allows the test set to be hung easily and two additional blank connections along with the vacuum connection allow for securing the open ends of the three lines when the test set is not in use. There is always a path from the low-side input to the low-side gage (fig. 19-45). The vacuum connection is also a direct connection to the low-side gage and the low-side input, however, a vacuum hose must be connected in order to depress and open the valve stem (similar to an automobile tire valve). There is always a path from the high-side input to the high-side gage. The valves control the path of the refrigerant supply input. If the LO valve is opened (turned counterclockwise), the refrigerant supply input has a clear path to the low-side gage, the low-side input, and the vacuum input (if a vacuum line is connected). If only the HI valve is opened, the refrigerant supply input has a clear path to the high-side gage and the high-side input. It would be illogical in refrigeration work to open both valves.



54.343
Figure 19-46.—Portable vaccum pump.

This test is listed in the Seabee Table of Allowance and will be the set you will use in following the directions given later for repair and servicing of refrigeration systems.

Another important piece of equipment you will use is the portable vacuum pump. The type listed in the Seabee Table of Allowance is a sealed unit consisting of a single piston vacuum pump driven by an electric motor. A vacuum pump is the same as a compressor except that the valves are arranged so that the suction valve is opened only when the suction developed by the downward stroke of the piston is greater than the vacuum already in the line. This vacuum pump can develop a vacuum close to -30 inches of mercury which can be read on the gage mounted on the unit (fig. 19-46). The pump is used whenever it is necessary to reduce the pressure in a refrigeration system below atmospheric pressure.

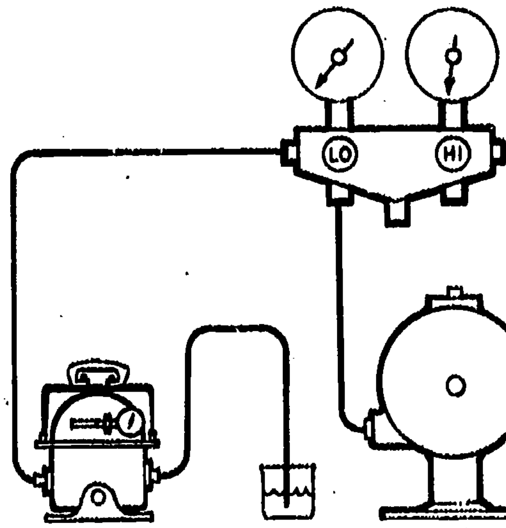
Hermetic refrigeration systems used by the Navy are manufactured by various manufacturers and, because of this, the connectors and size of tubing vary. The Table of Allowance provides for a refrigeration service kit which contains several adapters, wrenches, and other necessary materials to facilitate connection of different makes of systems to the refrigerant manifold test set, and vacuum pump lines. A table affixed to the lid of the storage container tells which adapter you should use for a particular make of refrigeration unit.

CHARGING A SYSTEM

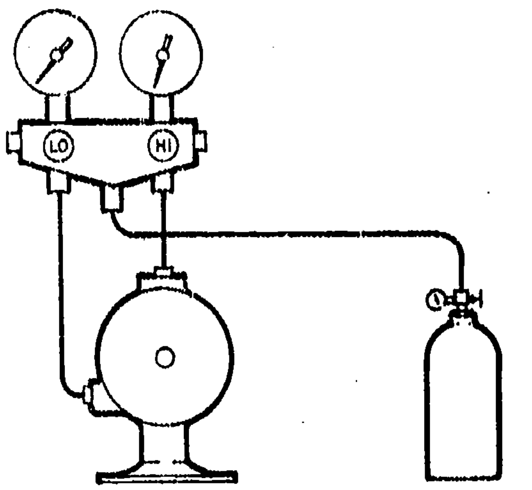
One of your duties will be charging a system with refrigerant. If a system develops a leak, you must repair it first, then charge the system. Similarly, if a component of the system becomes faulty and must be replaced, some refrigerant will be lost and the system will require charging.

Before a system can be charged, all moisture and air must be eliminated from the various components. This is accomplished by DRAWING A VACUUM on the system. To draw a vacuum on the system, connect the portable vacuum pump to the vacuum fitting on the refrigerant manifold test set (fig. 19-44) and connect the LO line to the suction service valve of the compressor using appropriate connectors if required. Turn the suction service valve to mid-position, so that vacuum drags from the compressor crankcase and suction line back through the evaporator, expansion valve, and liquid line. If the receiver service valve, condenser service valve, and the discharge service valve are open, then the pump will draw back through the receiver and condenser to the compressor.

Attach one end of 1/4-inch copper tubing to the vacuum pump discharge outlet. (See figure 19-47). Allow the vacuum pump to draw a vacuum of at least 25 inches. Submerge the other end of



54.344
Figure 19-47.—Connections for drawing a vacuum.



54.345
Figure 19-48.—Connections for low side charging.

the copper tubing under 2 or 3 inches of clean compressor oil contained in a bottle. Continue to operate the vacuum pump until there are no more bubbles of air and vapor in the oil, which indicates that a deep vacuum has been obtained.

Maintain the deep vacuum operation for at least 5 minutes, then stop the vacuum pump. Leaking discharge valves of a vacuum pump cause oil to be sucked up into the copper discharge tube. Keep the vacuum pump off at least 15 minutes to allow air to enter the system through any leaks. Then start the vacuum pump. A leaky system will cause bubbling of the oil in the bottle. Examine and tighten any suspected joints in the line, including the line to the vacuum pump. Repeat the test.

In most small refrigerating systems, LOW-SIDE CHARGING is generally recommended. It is normally used for adding refrigerant after repairs have been made. After the system has been cleaned and tested for leaks, it may be charged in the following manner (fig. 19-48):

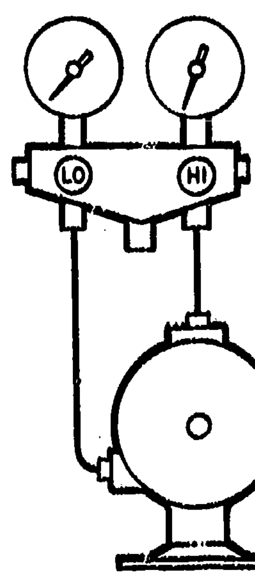
Connect a line from a refrigerant cylinder to the bottom center (refrigerant) connection on the refrigerant manifold test set. Be certain that the refrigerant cylinder is in a vertical position so that only refrigerant in the form of gas, not liquid, enters the system. Leave the connection loose and crack the valve on the cylinder. This will fill the line with gas and purge the air from the line. After this purging, tighten the connection.

Start the compressor and open the valve on the cylinder and the LO valve on the test set. Next, open the suction valve on the compressor to permit the gas to enter the compressor where it will be compressed and fed to the high side. Add the refrigerant slowly and check the liquid level indicator regularly until the system is fully charged. It is easy to check the receiver refrigerant level in some makes of condensing units because the receiver has minimum and maximum liquid level indicator valves, which show the height of the liquid level when opened. If a liquid-line sight glass is used, the proper charge may be determined when there is no bubbling of refrigerant as it passes by the glass. The sight glass will appear empty.

Again, be certain that the refrigerant cylinder is in the vertical position at all times. Otherwise, liquid refrigerant will enter the compressor and, liquid not being compressible, will damage the piston or other parts of the compressor.

PUMPING DOWN

One of the desired outcomes of the use of correct procedures for the repair of refrigeration systems is the prevention of loss of refrigerant. Whenever any component is removed from the system, the normally closed system is opened and, unless precautions are taken, refrigerant will be lost to the atmosphere. The best way to contain the refrigerant (gas and liquid) is to trap it in the condenser and receiver.



54.346
Figure 19-49.—Connections for pumping down.

This is accomplished by PUMPING DOWN the system.

To pump down the system, connect the refrigerant manifold test set as shown in figure 19-49 and close the receiver stop valve (by turning the stop valve inwards as far as it will go) and close the LO and HI valves.

Tighten the gland nut if it appears loose. Start the compressor with the compressor discharge and suction service valves in mid-position. Operate the compressor until the pressure in the low side of the system shows about a 20-inch vacuum on the compound gage. Stop the compressor unit.

If suction pressure does not go back to zero, crack the receiver service valve and let just enough refrigerant into the low side of the system to bring the suction pressure up to about 1 pound as read on the compound gage; then front seat the suction and discharge service valves. This procedure will trap practically all of the refrigerant in the condenser and receiver.

REMOVING REFRIGERANT FROM SYSTEM

The refrigerant is withdrawn from the condensing unit through the liquid valve at the receiver. Disconnect the liquid line from the liquid valve after pumping the evaporator down according to the manufacturer's instructions. It is not necessary to disconnect the liquid line in units that have a two-way liquid valve at the receiver. Provide a connection of 3 to 4 feet of soft copper tubing between the receiver valve and a clean, empty, precooled service cylinder. Weigh the cylinder frequently to avoid overfilling. Never fill a cylinder beyond 85% of its rated capacity because it may rupture from hydraulic pressure with a rise in temperature. Leave the flare nut loose at the refrigerant cylinder valve and crack the liquid valve on the receiver to purge air from the tubing. After purging, tighten all connections. Open the cylinder valves and liquid valve. If refrigerant flow to the cylinder is stopped, it may be necessary to lower the cylinder pressure by cooling the cylinder with cold water or ice. When the receiver pressure has been lowered to the pressure equivalent to the service cylinder temperature, all of the refrigerant has been removed. Close the cylinder and receiver valves. An overcharge of refrigerant is removed in the same way, except that the connection from the system is made at the compressor discharge service valve on the compressor head.

COMPONENT REMOVAL AND REPLACEMENT

The first step in the removal of any component in a refrigeration system for repair and/or replacement is to pump down the system. As you have learned, this procedure traps practically all of the refrigerant in the condenser and receiver and, by the proper positioning of the valves, the evaporator, expansion valve, and compressor (with connecting lines) can be removed with a minimum loss of refrigerant.

REMOVING EXPANSION OR FLOAT VALVES

In removing expansion or float valves, to help ensure good results, pump the system down to a suction pressure of just over zero; do this at least three times and then remove the expansion valve. Plug the opened end of the liquid line and evaporator coil to prevent air from entering the system. Repair or replace the expansion valve and connect it to the liquid valve. Crack the receiver service valve to purge air from the liquid line and the expansion valve. Connect the expansion valve to the evaporator coil inlet and tighten the connection. Pump a vacuum into the low side of the system to remove any air.

REPLACING EVAPORATOR

When necessary to replace an evaporator, pump down the system and disconnect the liquid and suction lines. Then remove the expansion valve and the evaporator. Make the necessary repairs or install a new evaporator as required. Replace the expansion valve, and connect the liquid and suction lines. Remove moisture and air by pumping a vacuum in the system. When the evaporator is back in place, pump a deep vacuum as in starting a new installation for the first time. Check for leaks and correct them if they occur. If leaks do occur, be certain to repair them; then pump into a deep vacuum. Repeat the process until no more leaks are found.

REMOVING THE COMPRESSOR

By pumping down the system, most of the refrigerant can be trapped in the condenser and the receiver. To remove the compressor from service, the compressor must be isolated by closing the suction and discharge service valves and then equalizing the pressure within the compressor. Both suction pressure in the crankcase and head pressure can be equalized to atmospheric pressure by either positioning the service valves to the vent position or cracking the connections to the compressor. When the lines to the compressor are disconnected, be certain to cover or block them to prevent dirt and moisture from entering them until another compressor can be installed or the original repaired and

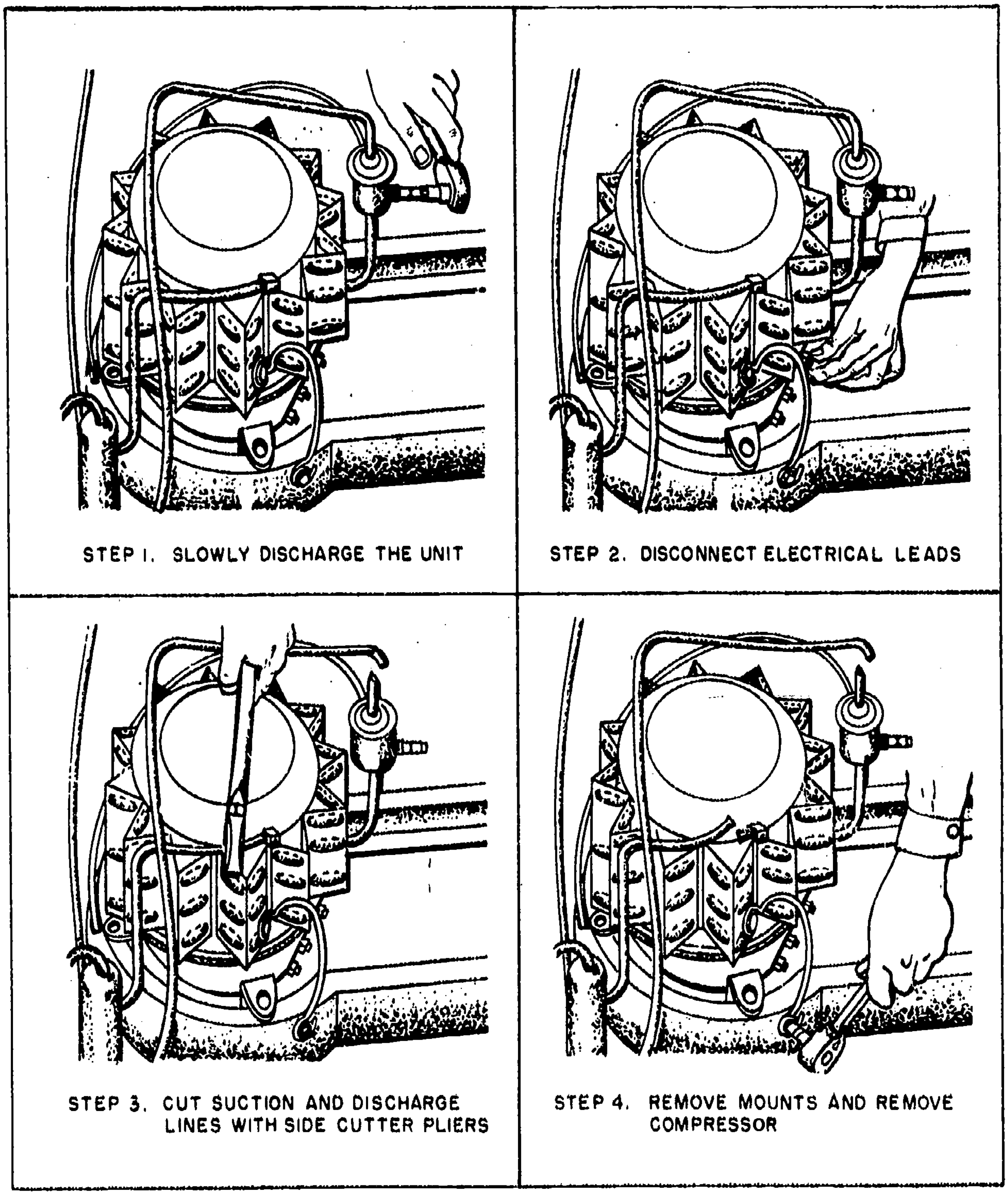


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Figure 19-50. —Removing defective hermetic compressor.

replaced. When a compressor has been installed, the air must be evacuated by drawing a vacuum on the system and then the system must be recharged.

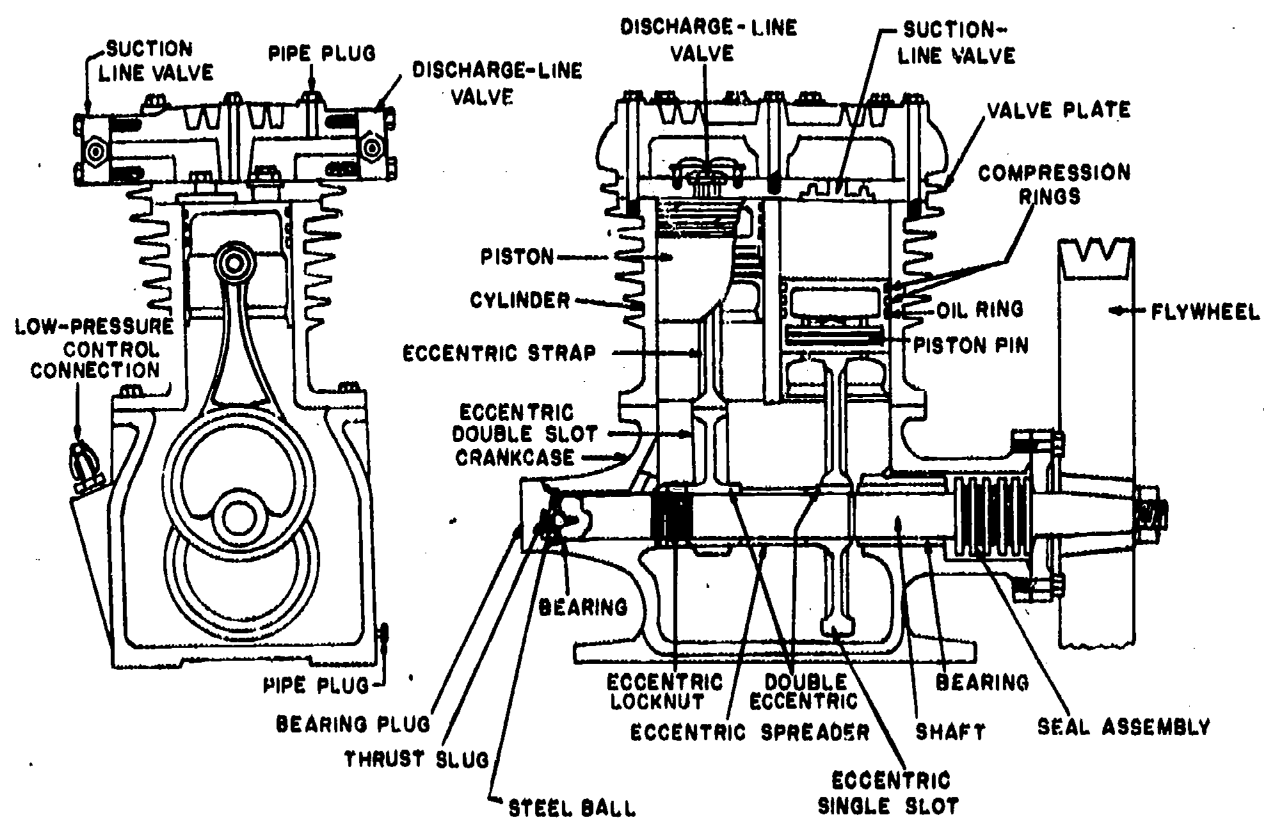
REMOVAL OF HERMETIC UNITS

The compressor unit of domestic refrigerators and freezers is almost always the small hermetically sealed type. These units do not lend themselves to easy repair as most of the maintenance performed on them consists of removal and replacement. Figure 19-50 shows the procedures for removal. Don't forget to pump down the system and equalize the suction and head pressures to atmosphere, if applicable. Guard against the spraying of refrigerant on personnel. After replacement, the procedures given earlier for removal of air and moisture, and recharging the system can be followed; however, the procedures may have to be modified because of the lack of some valves and connections. Follow the specific procedures of the manufacturer's manual.

MAINTENANCE OF OPEN-TYPE COMPRESSORS

Closely observe figure 19-51 which shows a vertical single-acting reciprocating compressor. Some of the duties you may perform in maintaining open-type compressors are discussed below.

SHAFT BELLOWS SEAL.—Refrigerant leakage often occurs at the shaft bellows seal, with consequent loss of charge. Install a test gage in the line leading from the drum to the compressor. Attach a refrigerant drum to the suction end of the shutoff valve outlet port. Apply the proper amount of pressure, as recommended in the manufacturer's instructions. Test for leaks with a halide torch around the compressor shaft, seal gasket, and seal nut; slowly turn the shaft by hand. If a leak is located at the seal nut, replace the seal plate, gasket, and seal assembly; if the leak is at the gasket, replace the gasket only. Retest the seal after reassembly. (This procedure is typical for most shaft seals on reciprocating open-type compressors.)



54.291X

Figure 19-51.—Vertical single-acting reciprocating compressor.

VALVE OBSTRUCTIONS.—Obstructions, such as dirt or corrosion, may be formed under seats of suction or discharge valves. To locate the source of trouble proceed as follows:

When the suction-side valve is obstructed, the unit tends to run continuously or over long periods. Connect the test gage assembly and start the unit. The pressure gage will not indicate an increase in pressure. The compound gage will fluctuate and will not indicate any decrease in pressure. Clean out any obstructions and recheck by again using the test gage assembly.

To determine whether there is a discharge valve leak, connect the test gage assembly and start the unit. Run it until the low-side pressure gage indicates normal pressure for the unit. Stop the unit. With an ear near the compressor housing, listen for leaking gas that may be evidenced by a hissing sound. Also watch the gages. If leakage caused by an obstruction is present, the low-side pressure will rise, and the high side will decrease until the pressures are equalized. A quick equalization of pressures indicates a bad leak that should be repaired immediately, or the compressor replaced.

COMPRESSOR LUBRICATION.—The oil level in the compressor crankcase should be checked once every 2 years. Attach the compound pressure gage to the suction service valve, then operate the unit to balance the pressure (indicated by zero reading of the gage); stop the unit. After a few minutes, remove the oil filler plug and measure the oil level in accordance with the manufacturer's instructions. Use only lubricant recommended by the manufacturer.

COMPRESSOR KNOCKS.—If a compressor knocks, you may have to disassemble the compressor to determine whether the cause of the knock is a loose connecting rod, piston pin, or crankshaft. Sometimes a loose piston pin can be detected without the complete disassembly. First, remove the cylinder head and valve plate to expose the top of the piston. Start the motor and press down on top of the piston with a finger. Any looseness can be felt at each stroke. The loose part should be replaced. Check the oil level first because knocks are often caused by oil levels that are too high. Always make sure that a low oil level is actually the result of a lack of oil rather than a low charge.

STUCK OR TIGHT COMPRESSOR.—A stuck or tight compressor will often occur as a result of poor reassembly after a breakdown repair. In such cases, determine where the binding occurs and reassembly the unit with correct tolerances; avoid uneven tightening of screws or seal covers.

INSPECTION

An inspection should be performed on the refrigeration unit from time to time for knocks, thumping, rattles, and so on. This should be done while the unit is in operation. If any of the external parts have excessive grease, dirt, or lint present, they should also be cleaned. Prior to cleaning, be sure and shut the unit off for safety reasons.

A careful check of the entire system, using instruments or tools, is essential to determine if there has been any loss of refrigerant. NO LEAK IS TOO SMALL TO BE FIXED. Each leak must be stopped immediately.

Some of the specific requirements for inspection of refrigeration systems are described below.

Inadequate lubrication of bearings and other moving parts are a continual source of trouble. This can usually be traced to a lack of maintenance resulting in low grease and oil levels or poor condition of lubricating oil.

Rusty or corroded parts discovered during the inspection should be cleaned and painted where applicable.

Hissing sounds at the expansion valve, low readings on the discharge pressure gage, and bubbles in the receiver sight glass all indicate an insufficient refrigerant charge.

Loose connections and worn or pitted switch contacts result in inoperative equipment or reduced reliability. Theremostats with burned contacts may produce abnormal temperatures in the cooled compartment.

Fans that are difficult to rotate by hand, have bent blades, or loose or worn belts are a source of trouble easy to locate and correct during inspections.

Air filters that are clogged with dirt should be cleaned or replaced during the inspection.

Hermetically sealed units should be inspected for evidence of leaks and excessive temperatures, and for excessive noise or vibration.

Open-type compressors should be checked for both oil and refrigerant leaks particularly at the shaft seal. In addition, a compression test must be made to reveal the pressure of worn rings, defective suction valve, or faulty discharge valve.

Condenser assemblies require properly directed and an adequate supply of coolant (air or water). Inspection should be made for the proper positioning of baffles, general cleanliness, and proper fan operation.

To sources of possible trouble associated with thermostatic expansion valves are the contact made by the equalizer and control bulbs. These areas must be inspected for loose contact, corrosion, and the pinching of the connecting tubes.

Accessories such as filter-dryer cartridges, oil traps, and strainers must be checked. If clogged, they will prevent the normal flow of refrigerant.

The above list is not intended to be complete. The NavFac P-322 manual must be consulted for complete inspection instructions.

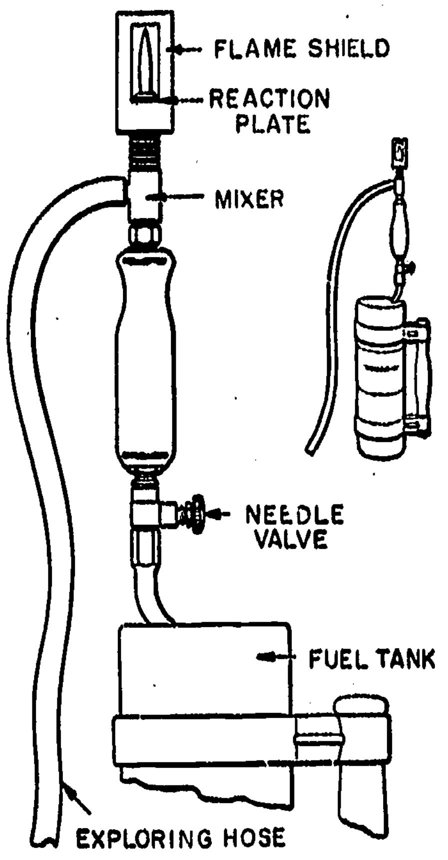
TESTING FOR REFRIGERANT LEAKS

The best time to test joints and connections in a system is when there is sufficient pressure to increase the rate at which the refrigerant issues from the leaking joint. There is usually always sufficient pressure in the high-pressure side of the system; that is, in the condenser, receiver, and liquid line, including dehydrators, strainers, line valves, and solenoid valves; but this is not necessarily true of the low-pressure side of the system, especially if it is a low-temperature installation, such as for frozen foods and ice cream, where pressures may run only slightly above zero on the gage. Where there is very little pressure, increase the pressure in the low-pressure side of the system by bypassing the discharging pressure from the condenser to the low-pressure side through the service gage manifold. Small leaks cannot be found unless the pressure inside the system is at least 40 to 50 psi, regardless of the method used to test for leaks.

Halide Leak Detector

The use of a halide leak detector is the most positive method of detecting leaks in a refrigerant system. Such a detector consists essentially of a torch burner, a copper reactor plate, and an exploring hose. (See fig. 19-52.)

Most detectors use either acetylene gas or alcohol as a fuel. Pressure for detectors which use alcohol is supplied by a pump. If a pump-pressure type of a ·hol-burning detector is used, be sure th he air pumped into the fuel tank is pure.



47.105

Figure 19-52.—Halide leak detector.

Atmosphere suspected of containing R-12 vapor is drawn, by venturi action, through the exploring hose into the torch burner of the detector. Here the air passes over the copper reactor plate, which is heated to incandescence. If there is a minute trace of R-12 present, the color of the torch flame will change from a blue (neutral) to green as the R-12 comes in contact with the reactor plate. The shade of green will depend upon the relative amount of R-12 present; a pale green indicates small concentrations and a darker green shows heavier concentrations. Excessive quantities of R-12 will cause the flame to burn with a vivid purple color. Extreme concentrations of R-12 may extinguish the flame by crowding out the oxygen available from the air. A halide torch is so sensitive that it is useless if the atmosphere is contaminated by excessive leakage of R-12. In testing for leaks of R-12, always start at the highest point of the system and work towards the lowest point because R-12 is heavier than air.

When a leak detector is used, best results are obtained if the following precautions are observed:

1. Be sure that the reactor plate is properly in place.

2. Adjust the flame so that it does not extend beyond the end of the burner. (A small flame is much more sensitive than a large flame. If difficulty is experienced in lighting the torch when it is adjusted to produce the necessary small flame, block the end of the exploring hose until the fuel ignites; then gradually open the hose.)

3. Clean out the exploring tube if the flame continues to have a white or yellow color. (A white or yellow flame indicates that the exploring tube is partially blocked with dirt.)

4. Check to see that air is being drawn into the exploring tube: this check can be made, from time to time, by holding the end of the tube to your ear.

5. Hold the end of the exploring tube close to joint being tested: this prevents dilution of the sample by stray air currents.

6. Move the end of the exploring hose tube slowly and completely around each joint being tested. (Leak testing cannot be safely hurried. There is a definite time lag between the moment when air enters the exploring tube and the moment it reaches the reactor plate: permit sufficient time for the sample to reach the reactor plate.)

7. If a greenish flame is noted at any time, repeat the test in the same vicinity until the source of the refrigerant is determined.

Always follow a definite procedure in testing for refrigerant leaks, so that no joints will be missed. Even the smallest leak is not to be considered negligible. However insignificant a leak may seem, it will eventually empty the system of its charge to the point where faulty operation will be encountered. The extra time spent in testing all joints will be justified. A refrigerant system should never be recharged until all leaks are discovered and definitely repaired.

Soap and Water Test

Soap and water may be used to test for leakage of any refrigerant having pressure higher than atmospheric pressure. Make a soap and water solution by mixing a considerable amount of soap with water to a thick consistency. Let it stand until the bubbles have disappeared, and then apply to the suspected leaking joint with a soft brush. Wait for bubbles to appear under the clear, thick, soap solution.

Find extremely small leaks by carefully examining suspected places with a strong light. If necessary, use a mirror to view the rear side of joints or other connections suspected of leaking.

MOTOR MAINTENANCE

Troubles associated with the electrical motors used to drive the compressors of mechanical refrigeration systems fall into two classes—mechaninical and electrical. Electrical defects will be covered later in this chapter.

Some compressors are belt driven from the electrical motor (fig. 19-19). For proper operation, both the belt tension and pulley alignment adjustments must be made. Belt tension should be adjusted so that a 1-pound force on the center of the belt, either up or down, will not depress it more than 1/2 inch. To adjust the alignment, loosen the setscrew on the motor pulley after tension adjustment is made. Be sure that the pulley turns freely on the shaft; add a little oil if necessary. Turn the flywheel forward and backward several times. When it is correctly aligned, the pulley will not move inward or outward on the motor shaft. Tighten the setscrew holding the pulley to the shaft before starting the motor.

Compressors also may be driven directly by a mechanical coupling between the motor and compressor shafts. It is extremely important that the two shafts are positioned so that they form a straight line with each other. The coupling on direct drive units should be realigned after repair or replacement. Clamp a dial indicator to the motor half coupling, with its pointer against the outer periphery of the compressor half coupling. Rotate the motor shaft, observing any fluctuations of the indicator. Move the motor or compressor until the indicator is stationary when revolving the shaft one full turn. Secure hold down bolts, then recheck.

MOISTURE IN SYSTEM

When liquid refrigerant that contains moisture vaporizes, the moisture will separate from the vapor. Because the vaporization of the refrigerant causes a cooling effect, the water that has separated can freeze. Most of the expansion and vaporization of the refrigerant occurs in the evaporator. However, a small amount of the liquid refrigerant vaporizes in the expansion valve, and the valve is cooled below the freezing point of water. As a result, ice can form in the expansion valve and interfere with its operation. If the needle in the valve freezes in a slightly off-seat position, the valve cannot permit the passage of enough refrigerant. If the needle freezes in a position far from the seat, the valve feeds too much refrigerant. In either case it is obvious that precautions must be observed to assure a moisture-free system.

A dehydrator is filled with a chemical known as a desiccant, which absorbs moisture from the refrigerant passing through the dehydrator. Dehydrators are installed in the liquid line to absorb moisture in the system after original installation. An arrow on the dehydrator indicates the direction of flow. Desiccants are in granular form and are composed of silica gel, activated alumina, or calcium sulfate. Do not use calcium chloride or chemicals that form a nonfreezing solution. These sometimes react with the moisture to form undesirable substances such as gums, sludges, or waxes. Follow the manufacturer's instructions in regard to limitations of dehydrators, as well as operation, recharging, replacing, and servicing.

LOOSE COPPER TUBING

In SEALED units, loose copper tubing is usually detected by the sound of rattling or metallic vibration. The defect is usually eliminated by bending the tubing carefully to the position of least vibration. Do not touch it against other tubing or parts at a point of free movement, and do not change the tubing pitch or the tubing diameter by careless bending.

In OPEN units, lengths of tubing must be well supported by conduit straps or other devices attached to walls, ceilings, or fixtures. Use friction-tape pads to protect the copper tube from the metal of the strap. Where two tubes are together in a parallel position, vibration can be prevented by wrapping and binding them together with tape. When two lines are placed in contact for heat exchange purposes, they should be soldered to prevent rattling and to permit better heat transfer.

DOORS AND HARDWARE

When HINGES must be replaced, because of lack of lubrication or other reasons, the use of exact duplicates is preferable. Loose hinge pins must be securely bradded. Where thrust bearings are provided, they are held in place by the pin.

The LATCH or CATCH is usually adjusted for proper gasket compression. If required to effect adjustment, shims or spacers may be added or removed. Latch mechanisms should be lubricated and adjusted for easy operation. Latch rollers must not bind when operated. Be sure to provide sufficient clearance between the body of the latch and catch, so that no contact is made. The only contact is made between the catch and the latch bolt or roller. These instructions also apply to safety door latches, when they are provided for opening the door from the inside, although it is locked from the outside.

Lack of complete gasket contact between the door overlap and the door frame is usually caused by WARPING of the door. Correct the condition by installing a long tapered wooden shim or splicer rigidly emplaced under the door seal. If this does not tighten the door to the frame, remove the door and either realign or rebuild it.

Repair or replace missing, worn, warped, or loose DOOR GASKETS. If the gasket is tacked on, rustproof tacks or staples should be used. If the gasket is clamped or held in place by the door frame or the door panel, an exact replacement is necessary. In either case, the gasket should be installed so that when the door is closed a complete and uniformly tight seal will result. If doors freeze closed due to condensation and subsequent freezing, apply a light coat of glycerine on the gaskets.

DEFROSTING

Cooling units in the 35 degree to 40 degree F refrigerators or cold storage rooms are generally defrosted automatically by setting the low-pressure control switch to a predetermined level. If this causes overload, with consequent heavy frosting of the coil, manual defrosting is necessary. Cooling units in 35 degree F and lower temperatures are defrosted manually. The most common method for manual defrosting is to spray water over the cooling coil, although defrosting can also be done by warm air, electric heating, or hot gas refrigerant.

In any case, the fans must not be in operation during the defrosting. Defrost plate-type evaporator banks in below-freezing refrigerators when ice has built up to a thickness of 1/2 inch, or when the temperature of the fixtures or the suction pressure is affected by the build-up of ice. Before removing frost from the plates, place a tarpaulin on the floor or over the contents of the refrigerator to catch the frost under the bank. Scrape frost from the plates with a wooden or plastic scraper or paddle about 6 inches wide, sharpened at the edges. Use of a metal scraper is difficult without resultant damage to the plates.

ELECTRICAL DEFECTS

The control systems for modern refrigeration systems are composed of many components that use or pass electrical power including compressor drive motors, pressure switches, thermostats, and solenoid stop valves. Although as a Utilitiesman third class or second class you are not responsible for troubleshooting these electrical components, you are responsible for being able to use the multimeter for locating opens, shorts, and grounds, and measuring voltage and current. To be able to meet this Qual, you will need to, at this point, study chapters 2, 4, 5, 14, and 15 of Basic Electricity, NavPers 10086-B. When you have finished studying these chapters, return to this chapter and learn how to locate opens, shorts, and grounds in refrigeration control circuits.

Opens

Figure 19-53 illustrates a simple refrigeration control system which will be used as an example in the explanation of how to locate opens, shorts, and grounds. You have learned the basics of electricity and how to use meters by your studying of the Basic Electricity manual. Here we will show you how to put your knowledge to work. Remember one fact—if you are not sure that you know what you are doing, call your supervisor or arrange for a Construction Electrician to assist you.

An open is defined as the condition of a component that prevents it from passing current. It may be a wire that is broken, a relay contact that is burned or pitted, a fuse that is blown, or a relay coil that has a broken or burned out coil winding. An open can be found in one of two ways. For series components such as the main disconnect switch, the fuses, the wire from C to D (see fig. 18-53) the relay contacts, and the wire from E to F, a voltmeter should be used. Set up the voltmeter to measure the source voltage (120 volts a-c, in this case). If the suspected component is open, the source voltage will be measured across it. To check part of the main disconnect switch, close the switch and measure from A to B. If the voltage is zero,

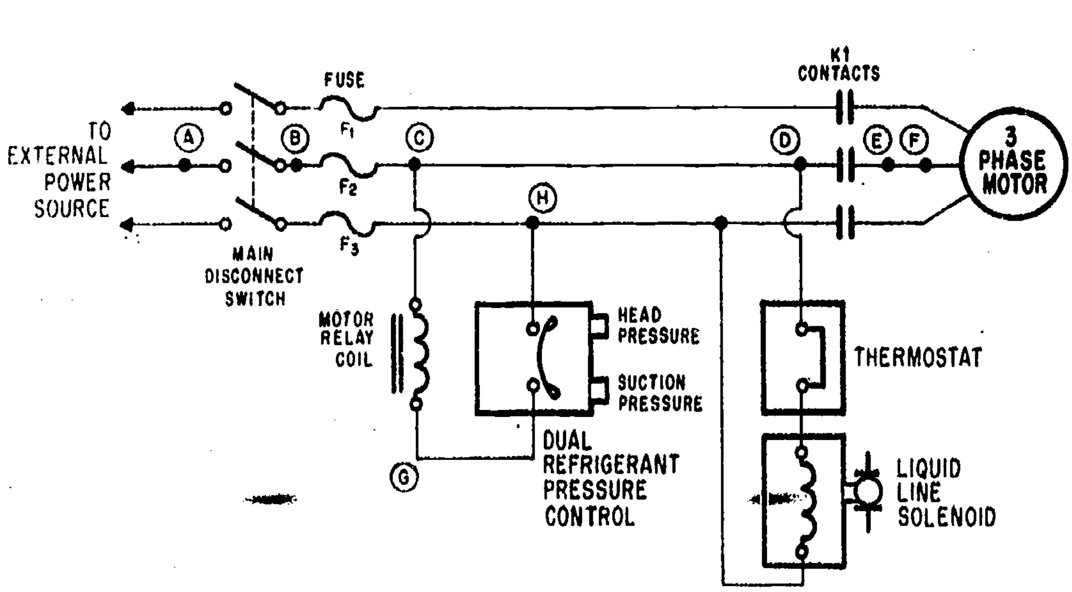


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Figure 19-53. —Simple refrigeration control system.

that part of the switch is good; if the voltage equals the source voltage, the switch is open. To check the fuse F2, measure across it, B to C. Measuring across C and D or E and F will check the connecting wires for opens. One set of the relay contacts can be checked with meter reads on D and E. These are just a few examples but the rule of series components can always be applied. Don't forget that the three sets of contacts of relay K1 will not close unless there is voltage across the relay coil, and the coil is not open or shorted. When testing any electrical circuit, be sure to follow all equipment and personal safety precautions that you have learned from the Basic Electricity manual.

Opens in components that are in parallel can not easily be found with a voltmeter because, as you know, parallel components have voltage across them at all times when the circuit is energized. In figure 19-53, the branch with the motor relay K1 and the dual refrigerant pressure control is considered a prallel circuit because when the main disconnect switch is closed and the fuses are good, there will be voltage between C and H regardless of whether the relay coil and pressure switch are open or not. To check for opens in these components use an ohmmeter set to a low range. Disconnect all power by opening (and locking out, if possible) the main disconnect switch. This will remove all power and ensure both personal and equipment safety. To check the motor relay K1 to see if its coil is open, put the ohmmeter leads on C and G. A reading towards infinity (extremely high resistance) indicates an open. The contacts of the dual refrigerant pressure control can be tested by putting the ohmmeter leads from G to H. Again a reading near infinity indicates open contacts. You may need to consult the manufacturer's manual for the physical location of the points G and H. Notice that the contacts of the control are normally closed when neither the head pressure nor the suction pressure is above their set limits.

Shorts

Shorts are just the opposite of opens. Instead of preventing the flow of current, they allow too much current to flow, often blowing fuses. The ohmmeter on its lowest range is used to locate shorts by measuring the resistance across suspected components. If the coil of the motor relay K1 is suspected of being shorted, put the leads on C and G. A lower than normal reading (usually almost zero) indicates a short. You may have to determine the normal reading by consulting the manufacturer's manual or by measuring the resistance of the coil of a known good relay. If fuses F2 and F3 blow and you suspect a short between the middle and bottom lines (fig. 19-53), put the ohmmeter leads between C and H. Again, a low reading indicates a short. Remember, in all operations using an ohmmeter, it is imperative that all power is removed from the circuit for equipment and personal safety. Don't fail to do this!

Grounds

Grounds are accidental connections between a part of an electrical circuit and ground due, perhaps, to physical contact through wearing of insulation or movement. Locating a ground follows the same procedure as locating a short because a ground is the result of the shorting of some point to ground. The earth itself, a cold water pipe, or the frame of a machine are all examples of ground points. To check to see if a component is shorted to ground, put one ohmmeter lead on ground and the other on the point suspected to be grounded and the rules for locating a short apply. Be sure to remove all power. It may even be wise to measure for the presence of voltage by using the voltmeter set to a range suitable for measuring source voltage. After it is determined that power does not exist, then the ohmmeter can be used.

The limited instruction presented here and in the chapters you were referred to in the Basic Electricity manual is not sufficient to qualify you as an electrician but should enable you to find such troubles as blown fuses, poor electrical connections, and the like. If the trouble appears more complicated than this, call your supervisor or arrange for a Construction Electrician's help.

Testing the Motor

As a Utilitiesman, you should be able to make voltage measurements in a refrigeration system to ensure that the proper voltage is applied to the drive motor as indicated on the motor's rating plate. If the proper voltage is applied (within 10%) to the terminals of the motor and yet it doesn't run, you must decide what course of action to take. If it is an open system (not hermetically sealed) it is the Construction Electrician's job to repair the motor. If it is a hermetically sealed unit, however, you will have available a piece of special test equipment that will alllow you to

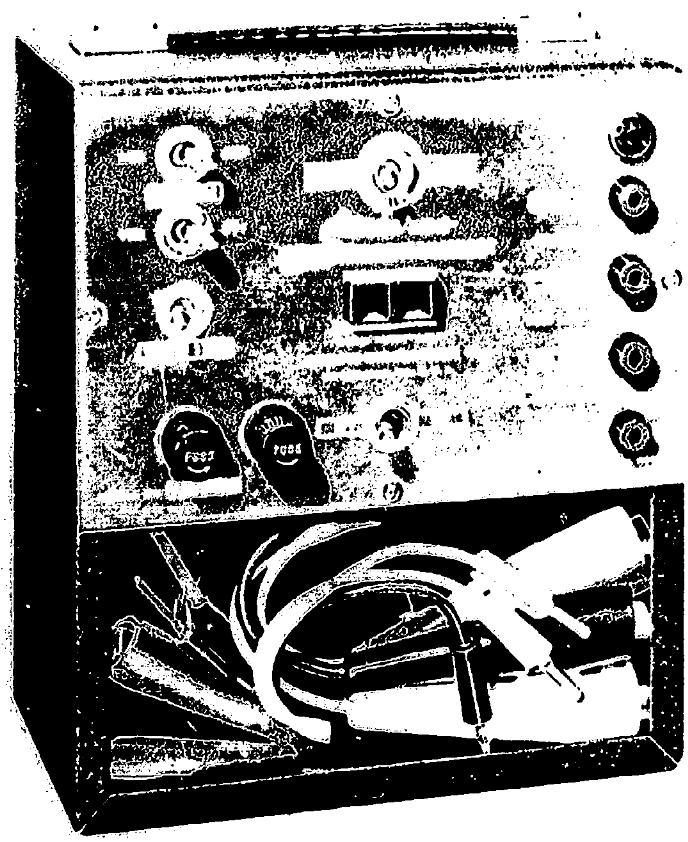

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Figure 19-54. — Hermetic Unit Analyzer.

complete further tests and perhaps make the unit operational again.

If the unit doesn't run, it may be because the motor rotor or compressor crankshaft is stuck (remember, in a hermetically sealed unit, they are one and the same). If you could apply electrical power to first try to move the motor in the correct direction and then reverse the power you might be able to rock it free and not have to replace the unit. This is one of the purposes of the Hermetic Unit Analyzer (fig. 19-54). To rock the rotor of an hermetically sealed unit, follow these steps:

1. Determine from the manufacturer's manual whether the motor is a split-phase or capacitor-start type.
2. Remove any external wiring from the motor terminals.
3. Place analyzer plugs in the jacks of the same color. If split-phase motor is used, put red plug in #3; if capacitor-start motor is used, put the red plug in jack #4 and select a capacity value close to the old one with the toggle switches.
4. Connect the test clips as follows:
   White to common
   Black to running winding
   Red to starting winding
5. Hold Push-To-Start button down and at the same time, operate the handle of the rocker switch from normal to reverse. The frequency of rocking should not exceed 5 times in a 15 second period. If the motor starts, be certain that the rocker switch is in the normal position before releasing the Push-To-Start button.

Additional tests can be made with the Hermetic Unit Analyzer, such as testing for continuity of windings and for grounds in windings. Procedures for these tests are given in the manual that accompanies the analyzer. Generally, if the rocking procedure does not result in a free and running motor, the unit must be replaced. Repair of these units is beyond the capabilities of the UT.

TROUBLESHOOTING CHECKLIST

With space being limited we have not attempted to cover all of the troubles you may encounter in working with refrigeration equipment. If you apply yourself, you will acquire a lot of additional information through on-the-job training and experience and by studying manufacturer's instruction manuals. You will also find table 19-3, "Troubleshooting Checklist — Refrigeration Systems," a useful guide in locating and correcting different troubles in refrigerating equipment.

DOMESTIC REFRIGERATORS AND FREEZERS

Domestic refrigerators and home freezer units contain up to 16 cubic feet of storage space. They are used by the Navy in quarters or hospital diet kitchens for food storage, in laboratories for preservation of biologicals and serums, and for similar purposes elsewhere. They are entirely self-contained units. The evaporator is located in the insulated refrigerated storage compartment, and the condenser is in a separate uninsulated compartment. All parts and compartments are housed in one cabinet, and assembly of the unit is always done at the factory. No unusual instal-

Table 19-4.—Troubleshooting Checklist—Domestic Refrigerators and Freezers

Trouble	Possible causes	What to look for and what to do
1. Unit fails to start	Wiring	Loose connections, broken wires, grounded leads, open contacts, corroded contacts, blown fuses, poor plug contacts, poorly soldered connections. Correct defects found
	Low voltage	Rated voltage should be ± 10 percent. Overloaded circuits: read the voltage across the compressor-motor terminals; if it reads 100 volts or under, the circuit is overloaded. Check the voltage at the fuse panel; if this voltage is low, the power supply voltage needs correction. Provide a separate circuit for the unit
	Compressor motor	Remove leads from the compressor motor. Apply 115 volts to the motor running winding terminals on the terminal plate from a separate two-conductor cable. Then, touch a jumper wire across both the starting and the running winding terminals. If the motor starts and runs, the trouble is isolated in the control or in the compressor motor thermostat. If the unit does not start, replace it
	Motor thermostat	Connect a jumper to shunt the thermostat from the line-side terminal of the thermostat across to the common terminal of the compressor motor. If the unit starts, the thermostat is open and should be replaced. Do not attempt to correct calibration of the thermostat. Replace the thermostat
2. Unit runs normally but temperature is too high	Temperature selector control set too high	Reset the dial to its normal position
	Temperature control out of adjustment	Readjust in accordance with the manufacturer's instructions.
	Poor air circulation in the cabinet	Paper on shelves; too much food in storage; other obstructions to proper air circulation. Maintain sufficient space in the cabinet for proper air circulation
	Damper control faulty	On models with this type of control it is best to replace the control or to follow the manufacturer's instructions
3. Unit runs normally but temperature is too low	Temperature selector control out of adjustment	Reset the control to a higher position

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Table 19-4. — Troubleshooting Checklist — Domestic Refrigerators and Freezers — Continued

Trouble	Possible causes	What to look for and what to do
3. Unit runs normally but temperature is too low (continued)	Temperature control out of adjustment	Readjust the control in accordance with the manufacturer's instructions
	Unit placed in cold location	If possible, remove the unit to a location where the ambient temperature is 55 degrees F. or over
	Temperature control bulb improperly located	Relocate the bulb in accordance with the manufacturer's instructions
	Damper open too far	Close the damper to restrict the air circulation in the cabinet, on units so equipped. Instruct the user on this point
4. Unit runs too long and temperature is too low	Temperature bulb improperly located or defective	Replace or relocate the bulb in accordance with the manufacturer's instructions. Be sure the bulb is securely attached to the evaporator. Replace defective bulbs
	Compressor	Refer to item 7
5. Unit does not run and temperature is too high	No power at outlet	Check the fuses, and replace burned-out ones
	Poor plug contact	Spread the plug contacts
	Control in "Off" position	Turn to the "Coldest" position, then back to the "Normal" position
	Temperature control inoperative	Examine the control main contacts; clean them with a magneto file or with fine sandpaper; replace them if they are badly burned or pitted. Do not use emery cloth. Check and replace the relay assembly, if necessary. If the temperature control main contacts are found open, try warming the temperature control bulb by hand. If this does not close the control contacts, the control bellows has lost its charge, and the control should be replaced
	Pressures in system not equalized	Wait during a period of about 5 minutes before trying to restart the unit. See item 3
	Open circuit in wiring	Make voltmeter or test-lamp checks to determine whether any part of the electrical wiring system is open, or any controls are inoperative. Correct defective connections, and replace worn or damaged controls

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Table 19-4.—Troubleshooting Checklist—Domestic Refrigerators and Freezers—Continued

Trouble	Possible causes	What to look for and what to do
5. Unit does not run and temperature is too high (continued)	Compressor thermostat open	See item 1
	Open motor windings	See item 1
6. Unit runs for short periods, temperature too high	Defrosting heater	On a unit equipped with a defrosting heater, check the defrosting cycle in accordance with the manufacturer's instructions. Ascertain whether the defrosting heater is turned off by making sure that no current flows through it during the refrigerating cycle
	Unit operates on thermostat	See item 9
7. Unit runs continuously, temperature too high	Moisture, obstruction, or restriction in liquid line	Before checking for moisture, be certain that the symptoms observed are not caused by improper operation of the defrosting heater, if so equipped. These heaters are wired into the cabinet wiring so that the control contacts short out the heaters when the contacts are closed. Thus the heaters are on only when the machine is off, when the control contacts open, and when the evaporator is on the defrost cycle. Check the control contacts to see that the defrosting heaters are off when the machine is running. At high ambient temperature, the unit will cycle on its thermostat. The evaporator will warm up over its entire surface if the liquid circulation is completely obstructed. If it is only partly obstructed, a part of the frost on the evaporator will melt. Under these conditions, the unit will probably operate noisily, and the motor will tend to draw a heavy current. If the liquid line is obstructed by ice, this ice will melt after the unit has warmed up. The unit will then refrigerate normally. If this obstruction occurs too frequently and spare units are available, replace the unit
	Broken valves	Exceedingly high current to the motor. No cooling in the evaporator and no heating in the condenser. Excessive compressor noise. Replace the hermetic compressor or replace the valves in an open-type compressor
	Clogged tubing	Check the tubing for damage, sharp bends, kinks, pinches, etc. Straighten the tubing, if possible, or replace the unit
	Refrigerant leaks or undercharged	The unit may tend to run normally but more frequently. The evaporator becomes only partly covered with frost. The frost will tend to

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Table 19-4. — Troubleshooting Checklist — Domestic Refrigerators and Freezers — Continued

Trouble	Possible causes	What to look for and what to do
7. Unit runs continuously, temperature too high (continued)	Refrigerant leaks or undercharged (continued)	build up nearest to the capillary tube while the section nearest to the suction line will be free from frost. As leakage continues, the frostline will move back across the evaporator. When the refrigerant is entirely gone, no refrigeration will occur. Units with large evaporators will not frost up unless the evaporator is mounted inside of the box. Test for leaks with a halide leak detector. Recharge the unit, if necessary.
	Cabinet light	Check the operation of the light switch, see that the light goes out as the door is closed
	Air circulation	See that sufficient space is allowed for air circulation. Relocate or reposition the unit, if possible
	Evaporator needs defrosting	Advise the user on defrosting instructions
	Gasket seals	Give them a thorough cleaning. If worn, they should be replaced
	Ambient temperature	Relocate the unit in a location where the ambient temperature ranges from 55 degrees to 95 degrees F.
	Defroster heater	On units so equipped, check the defroster heater circuit. See item 6
	Compressor suction valve sticks open or is obstructed by corrosion or dirt	Ascertain whether the condenser gets warm, and check the current drawn by the motor. If the condenser does not get warm and the current drawn is low, disassemble the compressor (open type) and check the action of the suction valve
	Compressor discharge valve sticks open or is obstructed	Connect the test gage assembly, run the unit until the low-side pressure is normal. With an ear in close proximity to the compressor, listen for a hissing sound of escaping gas past the discharge valve. The low-side pressure gage will rise, and the high side will drop equally until both are the same. Clean out obstructions
8. Unit runs too long, temperature too high	Condenser	Check for any obstruction in the path of air circulation around the condenser. Clean any dust accumulation

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Table 19-4. — Troubleshooting Checklist — Domestic Refrigerators and Freezers — Continued

Trouble	Possible causes	What to look for and what to do
8. Unit runs too long, temperature too high (continued)	Fan	On units so equipped, check to see that the fan blades are free to turn and that the fan motor operates
	Door seal	Clean seals around the door. Check closure of the door with a strip of paper between the gasket and the cabinet at all points around the door. The gasket should grip the paper tightly at all points
	Refrigerant	Check for leakage and undercharge of the refrigerant. See item 7
	User	Warn the user against too frequent opening of the door, storage of hot foods, heavy freezing loads, and other improper usage
9. Unit operates on thermostat, temperature too high	Voltage	Check voltage ± 10 percent of rated
	Defrosting heater	See that the defrosting heater is turned off
	Starting relay	Determine that the starting relay does not stick closed. Follow the manufacturer's instructions on methods of checking
	Condenser	Check the air circulation around the condenser; also check the operation of the fan
	Pressures not equalized	Wait 5 minutes after stopping, then restart; turn to the coldest position, then to the normal position
	Restrictions in liquid line	See item 7
	Thermostat	Thermostat may be out of calibration. Replace the thermostat
10. Noisy operation	Fan blades	If the blades are bent, realine them, and remove any obstructions. If the blades are so badly bent or warped that they cannot be realined, they should be replaced
	Fan motor	Check the motor mounting and tighten the connections
	Tube rattling	Adjust the tubes so that they do not rub together

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Table 19-4. — Troubleshooting Checklist — Domestic Refrigerators and Freezers — Continued

Trouble	Possible causes	What to look for and what to do
10. Noisy operation (continued)	Food shelves	Adjust them to fit tightly
	Compressor	Malfunctioning valves; loose bolted connections; improper alinement of open-type compressor. Replace the hermetic compressor; tighten the connections; realine the open-type compressor
	Floor or walls	Check to see that the floor is rigid, and whether the walls vibrate. Locate and correct any such sources of noise. Make corrections by bolting or nailing loose portions to structural members
	Belt	Check the condition of the motor belt. Replace it when it becomes worn or frayed
11. Unit uses too much electricity	Door	Check the door seal. See item 7
	Usage	Instruct the user on proper usage of the motor. See item 8. Check the overload
	Ambient temperature too high	See item 7. The unit will operate more frequently and over longer periods of time in a high-temperature atmosphere. Correct, if possible, by changing the location of the unit
	Defrost control	Check the defrost circuit according to the manufacturer's instructions
	Temperature control	Selector control dial set too low. Advise the user. Operate it as near to the "Normal" setting as possible
12. Stained ice trays	Poor cleaning procedures	Use soap and warm water to wash trays. Rinse them thoroughly. Do not use metal sponges, steel wool, or coarse cleaning powders

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lation procedures are involved, and units may be installed by activity personnel.

A domestic refrigerator should be placed in the coolest and most convenient location, away from the rays of the sun and near a source of power. It is also of utmost importance to place the refrigerator away from the wall about 2 to 3 inches to provide sufficient ventilation for the condensing unit. You may work with both conventional and combination refrigerators.

CONVENTIONAL refrigerators have a single evaporator which maintains low temperatures for frozen food and ice cube storage and, by means of an insulated baffle, operate the food storage compartment at temperatures above freezing.

COMBINATION refrigerators have separate freezer and food compartments. The freezer may have a separate door, and its comparative size may be 60 percent to 100 percent as much in volume as the food compartment. The temperature of the freezer is held near 0° F, and in the fresh food compartment the evaporator maintains temperatures varying from 35° to 40° F. Each compartment may be cooled by its own compressor, or a single evaporative arrangement may be used for both compartments. The operation is entirely automatic.

HOME FREEZERS provide storage space with temperatures of 0° F and lower, as well as a fast-freezing zone where limited quantities of fresh food may be frozen in a reasonably short time with minimum effects upon the temperatures of food already stored.

MAINTENANCE TROUBLESHOOTING

The UT must be able to perform various duties concerned with the maintenance and repair of domestic refrigerators and home freezers at Navy activities. This section provides information that will aid you in handling some of the common types of trouble. But let us remind you that the information given here is intended as a general guide and should, therefore, be used in conjunction with manufacturer's detailed instructions.

Manufacturer's Warranties

Whenever it becomes apparent that major repairs or replacements are required, maintenance personnel should ascertain whether the warranty period during which the refrigerator is guaranteed by the manufacturer has expired. This is especially true with regard to sealed components, factory-calibrated automatic temperature controls, and other factory-guaranteed parts. If attempts are made by activity maintenance personnel to adjust such components, it will usually be found that a clause in the warranty provides that such action results in cancellation of warranties.

Normal Operation

Troubleshooting of any type of refrigeration unit depends, in part, on your ability to compare normal operation with that obtained from the unit being operated. The left-hand column of Table 19-4 lists the troubles in terms of observable faults such as, the unit fails to run, temperature is too high or too low, the unit runs continuously or too long, or the operation is too noisy. Obviously, in order that you can detect this abnormal operation, you must first know what normal operation is.

CLIMATIC CONDITIONS affect running time to a great extent. A refrigerating unit generally will operate more efficiently in a dry climate. In an ambient temperature of 75 degrees F, the running period usually will approximate 2 to 4 minutes, and the off-period, 12 to 20 minutes. A self-starting clock connected to the motor terminals gives a simple check method for verification of the length of the period. If on-off periods are appreciably different from these, the trouble chart should be consulted for corrective action or the next step in narrowing down the location of the fault.

CHAPTER 20

AIR CONDITIONING

Air conditioning is the process of conditioning the air in a space in order to maintain a predetermined temperature-humidity relationship to meet comfort or technical requirements. This process involves both cooling and warming of the air and is usually referred to as winter and summer air conditioning. Winter and summer air conditioning is accomplished by installing both cooling and heating equipment in the air conditioning system. Of course, single units for cooling or heating may be used separately, as required.

The preceding chapter contained information that will be useful to you in duties involving air conditioning as well as refrigeration work. In this chapter you will be introduced to the operating principles of air conditioning systems, the environmental factors controlled by air conditioning, and their effects on health and comfort. We will examine the different types of oil- and gas-fired furnaces and refrigerative air conditioners, and explain the general procedures pertaining to the installation, operation, and maintenance of these systems. We will also cover the operation and maintenance of the controls employed with these systems, and the installation of oil tanks.

PRINCIPLES OF AIR CONDITIONING

The important factors involved in a complete air conditioning system include temperature control, humidity control, circulation of air, and purity or cleanliness of air. Complete air conditioning provides automatic control of these factors for both winter and summer outdoor weather conditions.

A furnace only heats the air, a fan only moves the air, and a cooling coil only cools the air. A complete air conditioning system should automatically cool or heat the air, increase or decrease the humidity, control the air movement, and clean the air.

TEMPERATURE

Three factors—temperature, humidity, and air motion—are closely interrelated in their effects on health and comfort. The term given to the net effects of these factors is EFFECTIVE TEMPERATURE. This effective temperature cannot be measured with the use of a single instrument; a psychrometric chart is used to aid in calculating the effective temperature when given sufficient known conditions relating to air temperatures and velocity.

Research has shown that a feeling of comfort is experienced by most persons in air where the effective temperature lies within a narrow range. The range of effective temperatures within which most people feel comfortable is called the COMFORT ZONE. Since winter and summer weather conditions are markedly different, the summer zone varies from the winter comfort zone. The specific effective temperature within the zone at which most people feel comfortable is called the COMFORT LINE (see figure 20-1).

HUMIDITY

When air is at high temperature and is saturated with moisture, it makes us feel uncomfortable. However, with the same temperature and the air fairly dry, we may feel quite comfortable. Dry air, as it passes over the surface of the skin, will evaporate the moisture more readily than damp air and, consequently, produce a greater cooling effect. However, air may be so dry that it causes us discomfort. Air that is too dry causes the surface of the skin to become dry and irritates the membranes of the respiratory tract.

HUMIDITY is the amount of water vapor in a given volume of air. RELATIVE HUMIDITY is a term used to express the amount of water vapor in a given amount of air in comparison with the amount of water vapor the air would hold at that temperature if it were saturated.

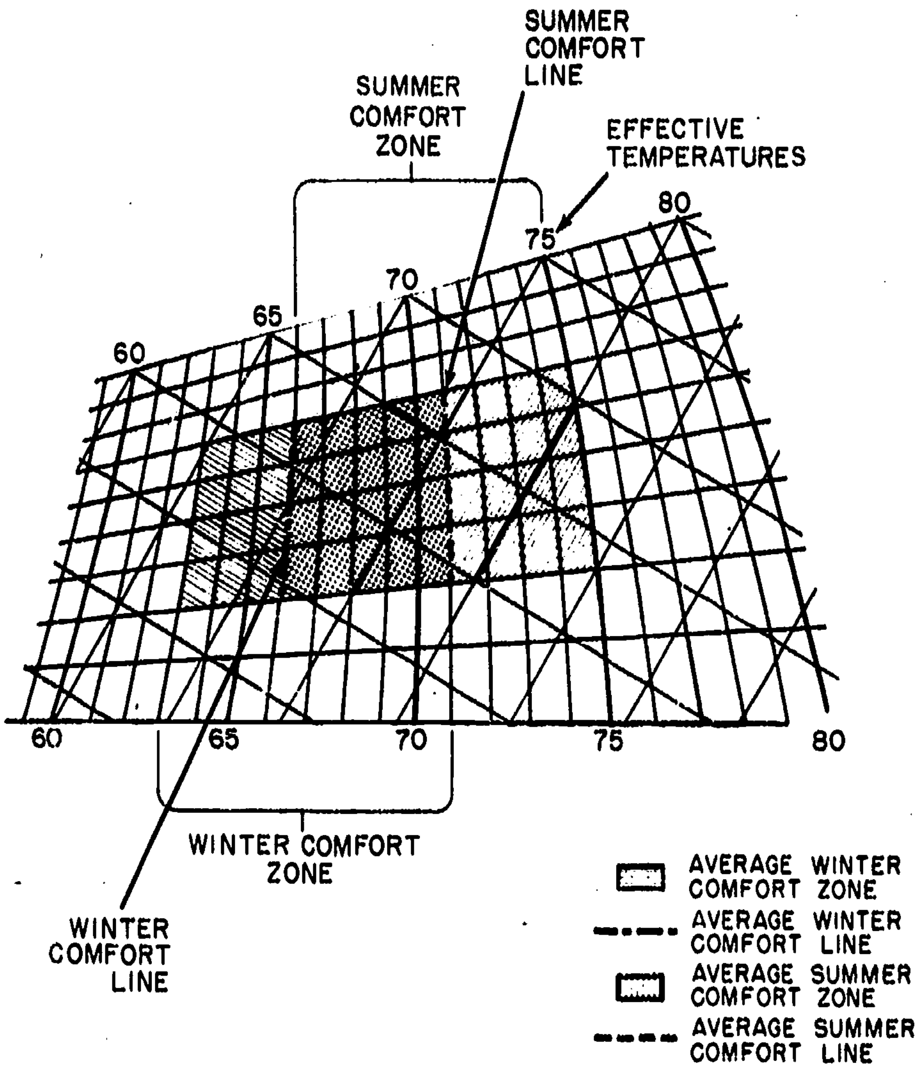

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Figure 20-1.—Comfort zones and lines.

Relative humidity is determined by using a sling psychrometer. It consists of a wet-bulb thermometer and a dry-bulb thermometer, as shown in figure 20-2. The wet-bulb thermometer is an ordinary thermometer similar to the dry-bulb thermometer except that the bulb is enclosed in a wick which is wet with distilled water. This bulb is called the wet bulb and is cooled as the moisture evaporates from it while it is being spun through the air. This causes the wet-bulb thermometer to register a lower temperature than the dry-bulb thermometer. Tables and charts have been designed using these two temperatures in order to arrive at a relative humidity for certain conditions.

Figure 20-3 is called a comfort zone chart. The comfort zone is the range of effective temperatures over which the majority of adults feel comfortable. In looking over the chart, note that the comfort zone represents a considerable area. The chart shows the wet- and dry-bulb temperature combinations which are comfortable to the majority of adults. The summer comfort zone extends from 66 °F. effective temperature to 75° F. effective temperature for 98 percent of all personnel. The winter comfort zone extends from 63° F effective temperature to 71° F effective temperature for 97 percent of all personnel.

Dew Pont Temperature

The dew point depends on the amount of water vapor in the air. If the air at a certain temperature is not saturated, that is, if it does not contain all the water vapor it can hold at that temperature, and the temperature of that air

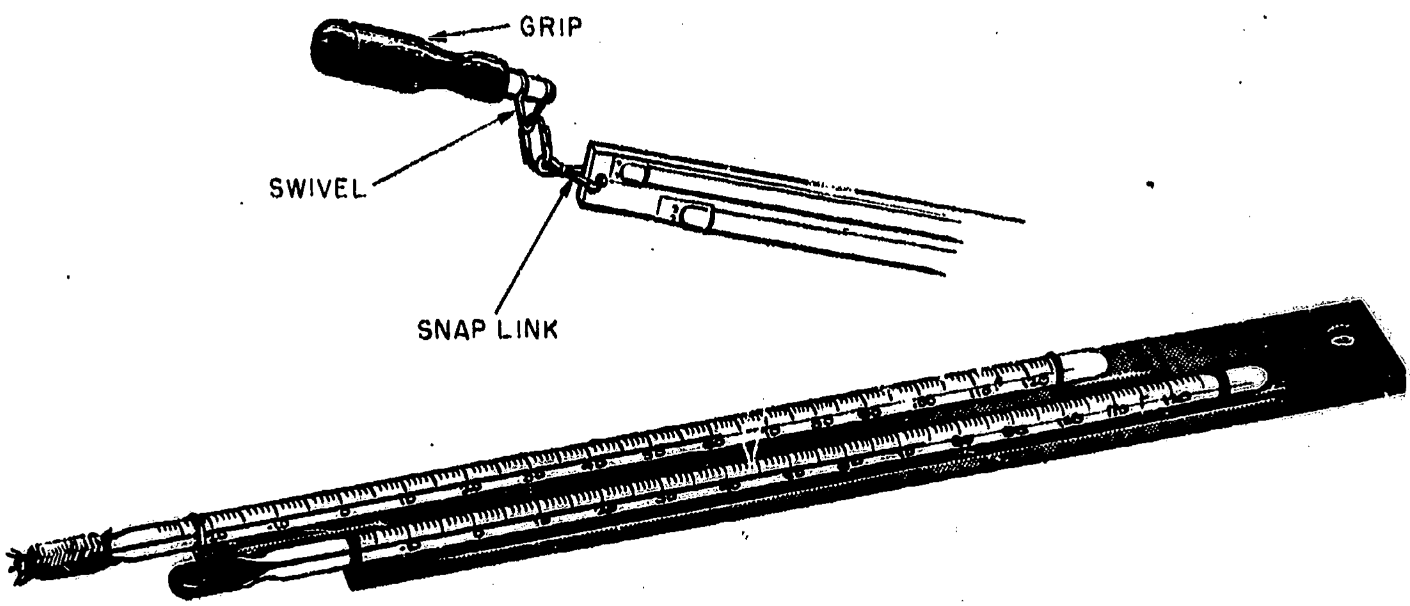

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Figure 20-2. — A standard sling psychrometer.

falls, a point is finally reached at which the air is saturated for the new and lower temperature, and condensation of the moisture begins. This is the dew point temperature of the air for the quantity of water vapor present.

Relationship of Wet-bulb, Dry-bulb, and Dew Point Temperatures

Definite relationships exist between the wet-bulb, dry-bulb, and dew point temperatures. These relationships are:

1. When the air contains some moisture but is not saturated, the dew point temperature is lower than the dry-bulb temperature, and the wet-bulb temperature lies between them.
2. As the amount of moisture in the air increases, the amount of evaporation (and, therefore, cooling) decreases. The difference between the temperatures grows less.
3. When the air becomes saturated, all three temperatures are the same and the relative humidity is 100 percent.

To HUMIDIFY air is to increase its water vapor content. To DEHUMIDIFY air is to decrease its water vapor content. The device used to add moisture to the air is called a humidifier, while a dehumidifier is used to remove moisture from the air. The control device which is sensitive to various degrees of humidity is called a HUMIDISTAT.

Methods for humidifying air in air conditioning units usually consist of an arrangement which causes air to pick up moisture. One arrangement may consist of a heated water surface over which conditioned air passes and picks up a certain amount of water vapor by evaporation, depending upon the degree of humidifying required.

Another arrangement which is used to humidify air is by spraying or washing the air, as it passes through the air-conditioning unit.

During the heat of the day, the air usually absorbs moisture. As the air cools at night, it may reach the dew point and give up moisture which is deposited on objects. This principle is used in dehumidifying air by mechanical means.

Dehumidifying equipment for air conditioning usually consists of cooling coils within the air conditioner. As warm humid air passes over the cooling coils, its temperature drops below the dew point and some of its moisture condenses into water on the surface of the coils. The condensing moisture gives up latent heat, thereby creating a part of the cooling load which must be overcome by the air-conditioning unit. For this reason, the relative humidity of the air entering the conditioner has a definite bearing on the total cooling load. The amount of water vapor that can be removed from the air depends upon the air over the coils, and the temperature of the coils.

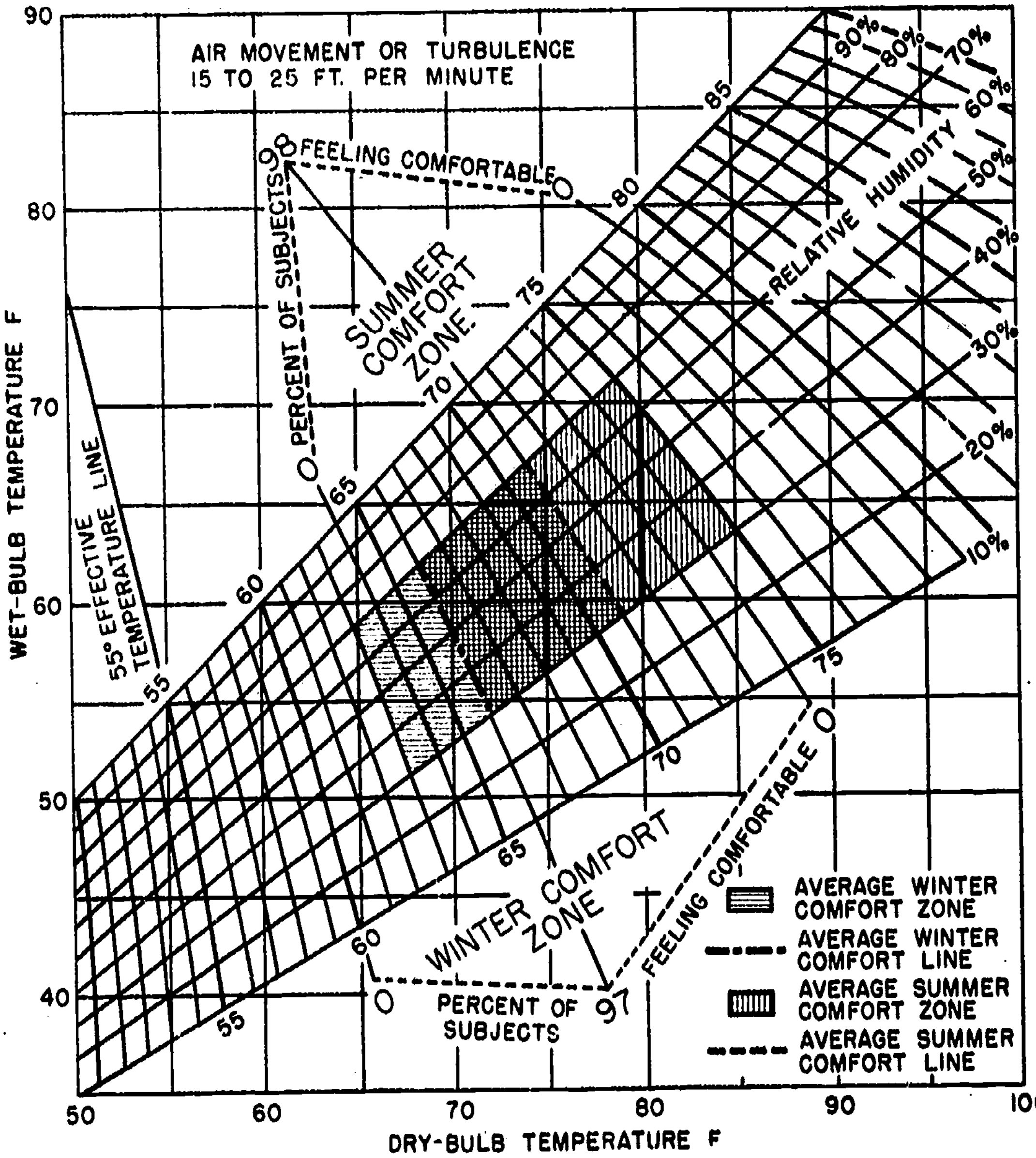

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Figure 20-3.—Comfort zone chart.

PURITY OF AIR

The cleanliness of air is important from the standpoint of health. The air should be free from all foreign materials, such as ordinary dust, rust, animal and vegetable matter, pollen, carbon (soot) from poor combustion, fumes, smoke, and gases. Not only is foreign matter of these types harmful to the human body, but in addition, the human body is endangered by the bacteria and harmful germs that are carried about by such foreign particles. For this reason, the outside air brought into a space or the recirculating air within a space should be filtered during the air-conditioning process.

The air in an air conditioner may be purified or cleaned by the use of filters, by a process of air washing, or by the use of electricity.

FILTERS may be designed as permanent or throw-away types. (See fig. 20-4.) They are usually made of fibrous materials. The fibers collect the particles of dust and other foreign matter from the air as it passes through the filter. In some cases the fibers are dry, while in others they have a viscous (sticky) coating. Filters normally have a large dust holding capacity.

When filters become dust-laden they must be either discarded or cleaned. This depends upon

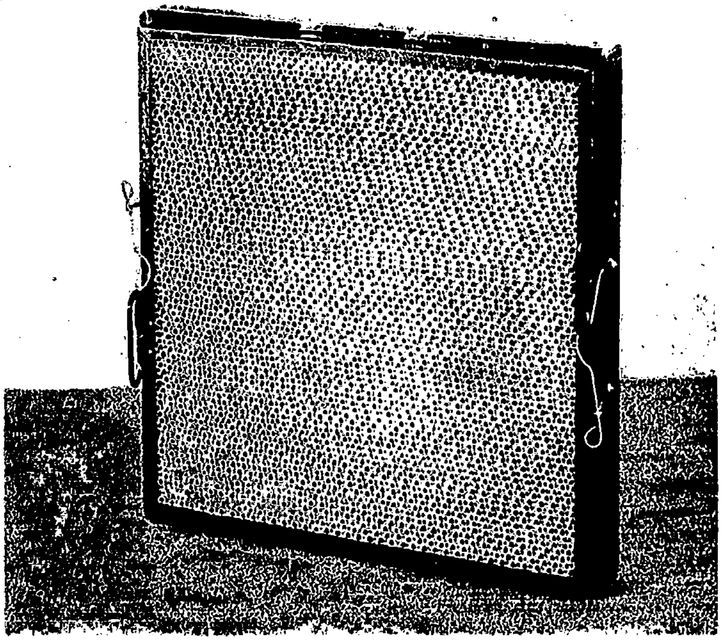

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Figure 20-4.—Air filter.

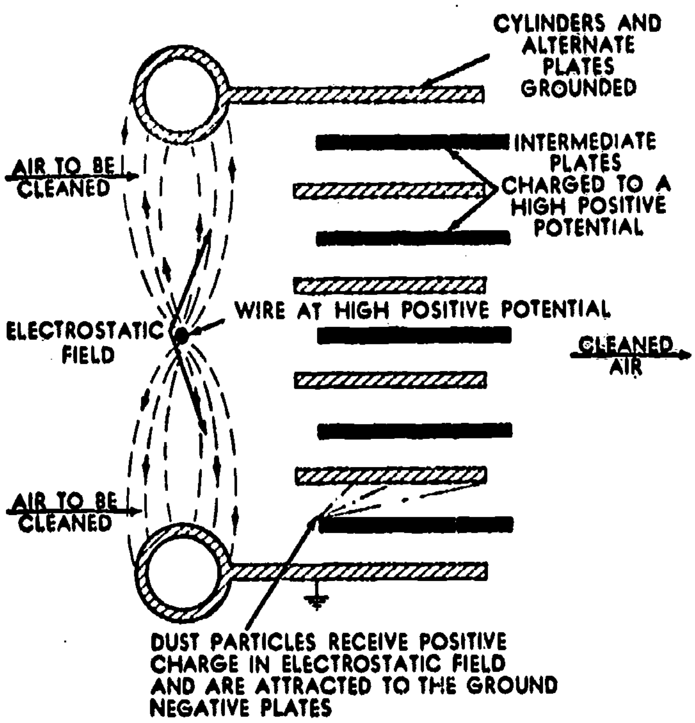

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Figure 20-5.—Diagram of an electrostatic filter.

the type of filter. Permanent filters are usually cleaned. The cleaning solution used to clean filters depends upon the composition of the filter. The manufacturer's recommendations and instructions should be followed in this case. Throwaway filters are only one-time filters. When they become dust-laden they must be discarded.

Often water sprays are used to recondition air by washing and cleaning it. These sprays may also serve to humidify the air or dehumidify it to some extent. During the winter season, the water sprays will add a considerable amount of moisture to the air if the water is warm. In the summer season, if the spray is kept cool it will tend to take moisture out of the air and make it drier. In this way, washing the air serves to either humidify or dehumidify, and to clean it—all in one operation.

In some large air-conditioning systems, air is cleaned by electricity. In this system, electrical precipitators remove the dust particles from the air. The air is first passed between plates where the dust particles are charged with electricity, then the air is passed through a second set of oppositely charged plates, which attract and remove the dust particles (fig. 20-5). This method is by far the best method of air cleaning, but the most expensive.

CIRCULATION OF AIR

The circulation of air is important in air conditioning. The velocity of air determines to a great extent what temperature and humidity is required in order to produce comfortable conditions. (The chart in figure 19-3 is one of a set of charts and is based on an air movement of 15 to 25 feet per minute.) We know from experience that a high velocity of air produces a cooling effect on human beings. However air velocity does not produce a cooling effect on a surface that does not have exposed moisture. A fan does not cool the air, but merely increases its velocity. The increased velocity of air passing over the skin surfaces evaporates the moisture at a greater rate, thereby cooling the individual. For this reason, circulation of air has a decided influence on comfort conditions. Air may be circulated by gravity or mechanical means.

When air is circulated by gravity, the cold, and therefore heavier air tends to settle to the floor forcing the warm and lighter air to the ceiling. When the air at the ceiling has been cooled by some type of refrigeration it will settle to the floor and cause the warm air to rise. The circulation of air in this type of system eventually stops when the temperature of the air at the ceiling and at the floor becomes the same.

Circulation of air by mechanical means may be accomplished by axial or radial (squirrel cage) fans either mounted directly on electric motor shafts or mounted on a separate shaft and driven by pulleys and belts (fig. 20-6). When either the axial or radial fan is mounted in an enclosure, it is often called a blower.

Circulation of air by mechanical means may be accomplished by various types of fans. Some fans are mounted directly on electric motor shafts, while others are mounted on a separate shaft and powered by electric motors through pulleys and belts.

GRAVITY WARM-AIR HEATING SYSTEMS

Gravity warm-air heating systems operate because of the difference in specific gravity (weight) of warm air and cold air. Warm air is lighter than cold air and rises if cold air is available to replace it.

HEATING EQUIPMENT

Heating equipment for complete air-conditioning systems is classified according to the

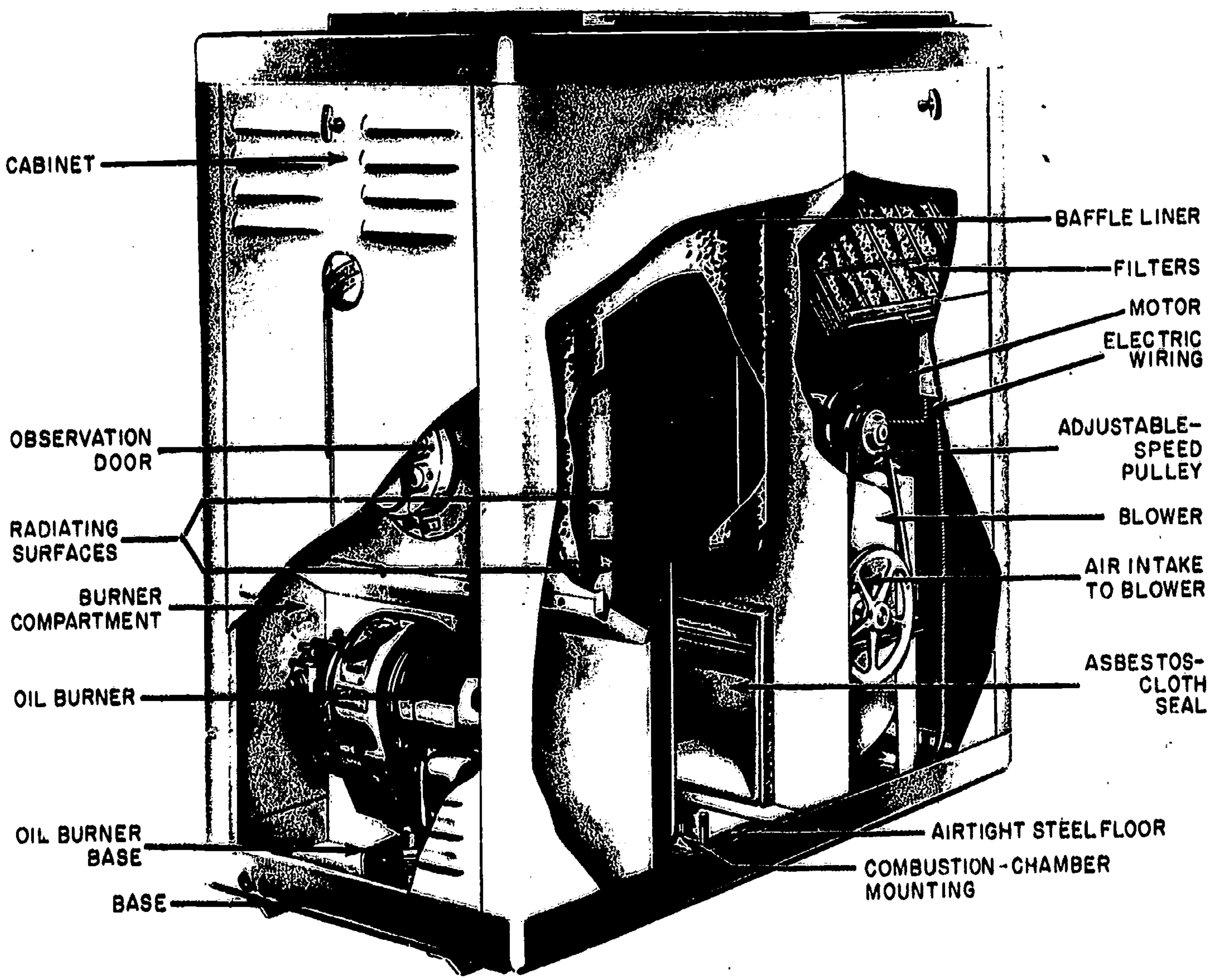

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Figure 20-6. — Cutaway view of a typical oil-designed furnace.

type of fuel burned, the Btu capacity of the furnace, and the method of circulating the warm air. Two types of warm air furnaces are the gravity and forced air circulating types.

Gravity furnaces are often installed at floor level. These are really oversized jacketed space heaters. The most common difficulty experienced with this type of furnace is a return-air opening of insufficient size at the floor. Make the return-air opening on two or three sides of the furnace wherever possible. Provide heat insulation above the furnace top to avoid a possible fire hazard.

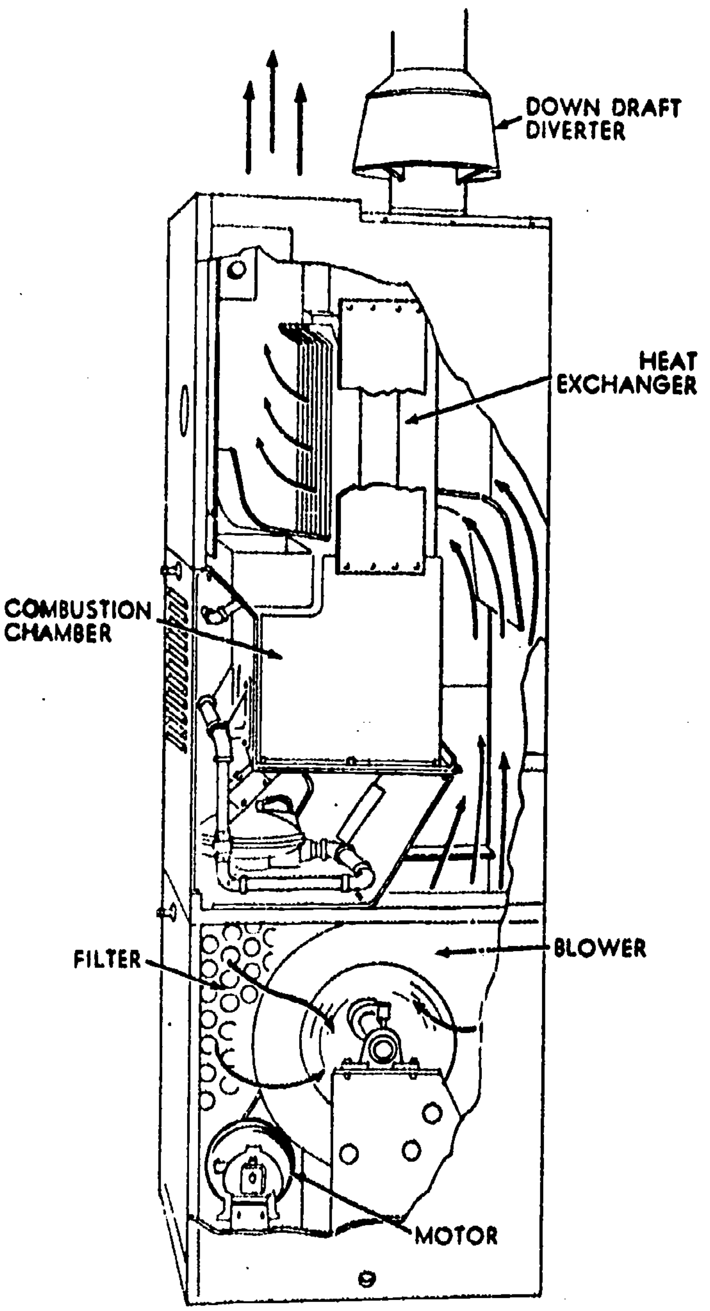

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Figure 20-7. —Gas-fired vertical warm-air furnace.

FORCED WARM-AIR FURNACES

The majority of the furnaces produced today are of the forced warm-air type. This type furnace includes the elements of a gravity warm air system plus a fan to ensure adequate air distribution. It may include filters, and a humidifier to add moisture to the air. The inclusion of a positive pressure fan makes possible the use of smaller ducts and the extension of the system to heat larger areas without the need for sloping ducts. It is possible to heat rooms located on floors below the furnace if necessary. Forced air furnaces are manufactured in a variety of designs. A typical oil-fired furnace is shown in figure 20-6. A typical gas-fired furnace is shown in figure 20-7.

In a forced-air system, the fan or blower is turned on and off by a blower control which is actuated by the air temperature in the bonnet or plenum. (See fig. 20-8.) The blower control starts the fan or blower when the temperature of the heated air rises to a set value and turns the fan or blower off when the temperature drops to a predetermined point. Thus, the blower only circulates air which is of the proper temperature.

Humidifiers used with forced warm air heating systems are usually of the pan type shown in figure 20-9. Unless the water is relatively free of solids, these humidifiers require frequent attention since the float may stick in the open position or the valve may clog. Overflowing of the pan may result in a cracked heating section, and a stopped-up inlet valve will make the humidifier inoperative.

The drum type evaporative humidifier uses an evaporation pad in the shape of a wheel. The slow turning wheel is submerged in the water in the lower pan where the sponge-like plastic foam material becomes saturated with water. The wheel lifts this portion of the pad and exposes it to the warm dry air flowing through it. The air will then absorb more moisture because of lower relative humidity at the higher temperatures.

OIL BURNERS

Oil burners may be separated into various classes, such as domestic and industrial. Since

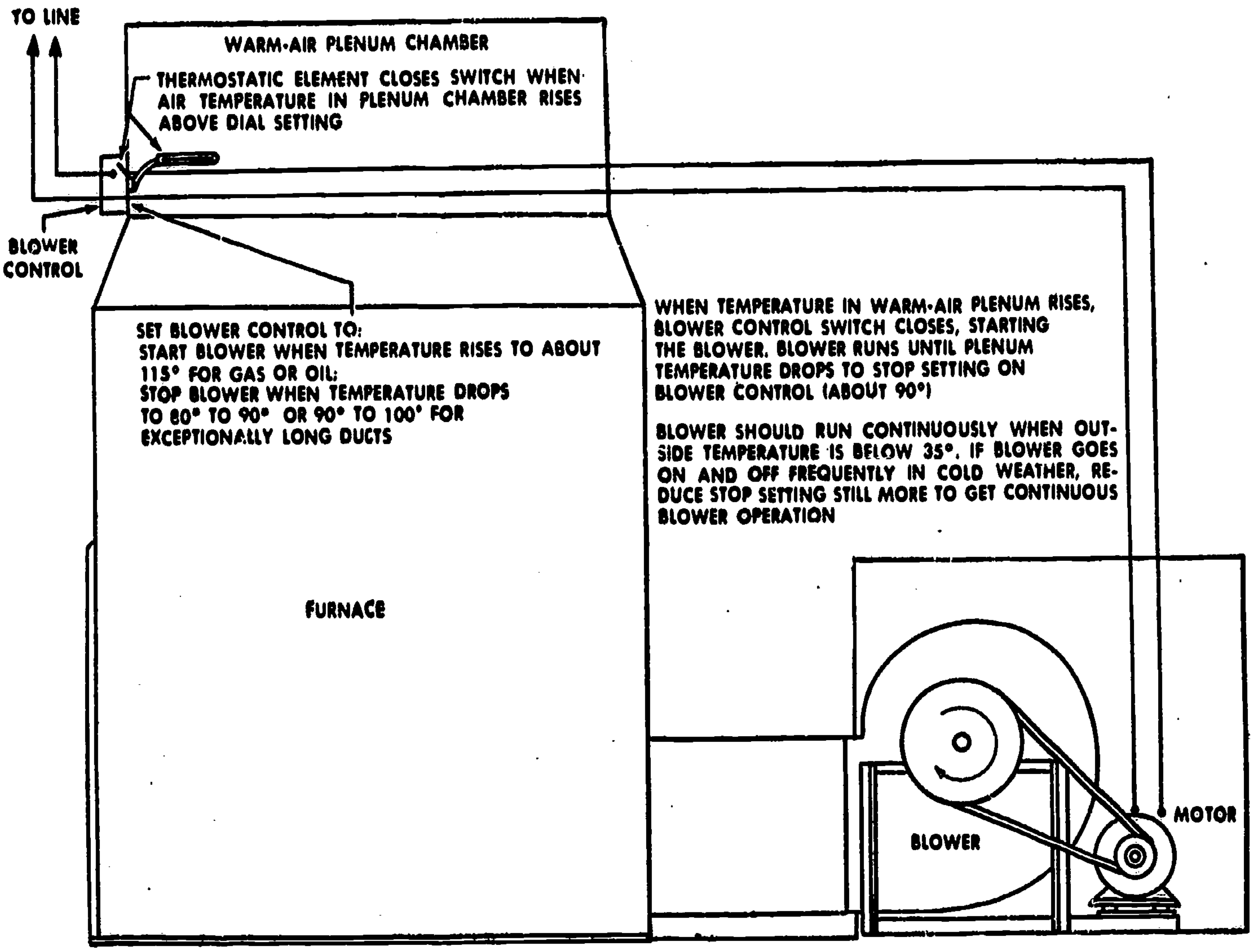

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Figure 20-8.—Electrical circuit showing how blower control operates blower motor when temperature in plenum rises.

domestic oil burners are used almost universally in warm air furnaces, they are the only ones covered in detail in this chapter.

Domestic Oil Burners

Domestic oil burners are usually electrically power driven and are used in small central heating plants.

Domestic oil burners atomize the oil. They also deliver a predetermined quantity of oil and air to the combustion chamber, ignite it, and automatically maintain the desired temperature. Domestic oil burners are classified according to various methods, none of which is entirely satisfactory because of the overlapping among a great number of models. Classification may be by type of ignition, draft, operation, method of oil preparation, or features of design and construction.

Design and Construction

One of the most common types of domestic oil burners is the PRESSURE ATOMIZING GUN-TYPE BURNER. Gun-type burners atomize the oil by fuel oil pressure. The fuel oil system of a pressure atomizing burner consists of a strainer, pump, pressure-regulating valve, shut off valve, and atomizing nozzle. (See fig. 20-10.) The nozzle and electrode assembly includes oil pipe, nozzle holder, nozzle, and strainer, electrode insulators, electrodes, supporting clamp for all parts, and static disk. The oil pipe is a

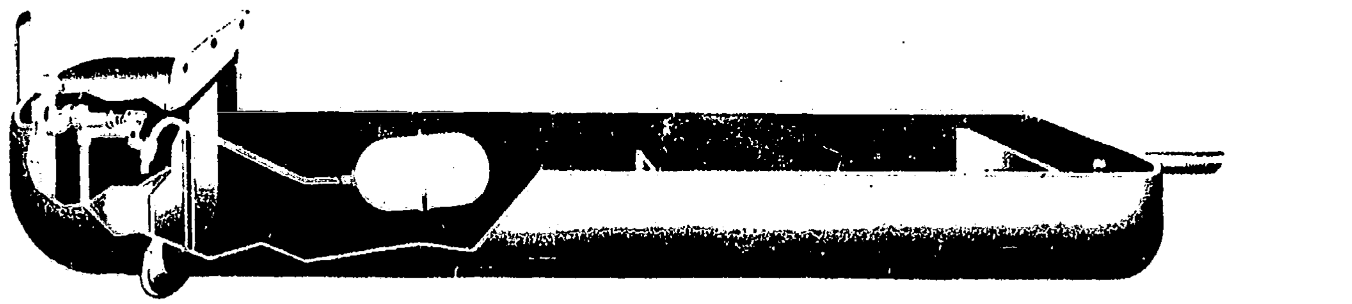

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Figure 20-9. —Cutaway view of typical humidifier.

steel rod with a fine hole drilled through it. This reduces oil storage in the nozzle to a minimum, to prevent squirting at the nozzle when the burner shuts off.

The air system consists of a power-driven blower with means to throttle the air inlet, an air tube which surrounds the nozzle and electrode assembly, and vanes or other means to provide turbulence for properly mixing air and oil. The blower and oil pump are generally connected by a flexible coupling, which is connected to the burner motor. Atomizing nozzles can be furnished to suit both the angle of spray and the oil rate of a particular installation. Flame shape may also be varied by changing the design of the air exit at the end of air tubes; oil pressures are usually about 100 psi, but pressures considerably greater are sometimes used.

Electric ignition is almost exclusively used. Electrodes are located near the nozzle, but must not be in the path of the fuel oil spray. The step up transformer provides the high voltage (usually 10,000 volts) necessary to make an intense spark jump across the electrode tips.

Oil Burner Controls

The purpose of oil burner controls is to provide automatic, safe, and convenient operation of the oil burner. The system is designed to maintain the desired room temperature, to start the burner as required, and to ignite the fuel to initiate combustion. However, in case trouble arises during operation, the burner must be stopped and further operation be prevented until the trouble has been corrected.

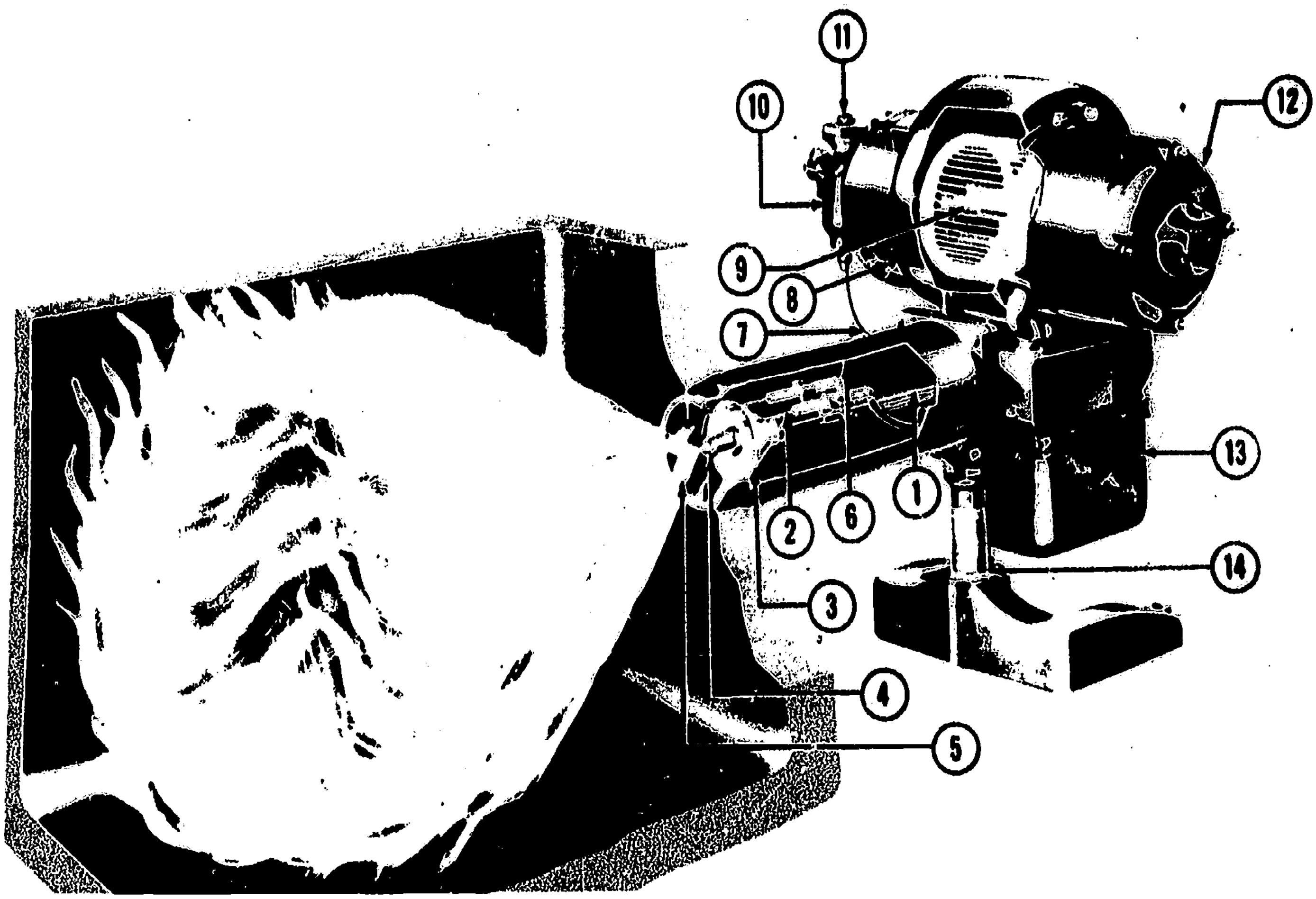
Oil burner controls are essentially the same as stoker or gas controls. The only difference is that the oil-burner has, in addition, two ignition electrodes and a primary or safety ignition control. A diagram of a typical forced air control system is shown in figure 20-11.

IGNITION ELECTRODES. — The fuel is ignited by the heat of a spark jumping between two ignition electrodes. (See fig. 20-12.) The voltage necessary to cause the spark to jump is much more than line voltage available. Therefore, an electric transformer is used to step up the line voltage to approximately 10,000 volts.

PRIMARY CONTROL. — The burner primary control is electrically connected between the thermostat and the burner, as illustrated in figure 20-11, and performs several functions. The primary control closes the motor and ignition circuits when the thermostat calls for more heat. It breaks the motor circuit and stops the burner when the motor first starts if the fuel fails to ignite or if the flame goes out. The control prevents starting of the burner in case of electrical failure, until all safety devices are in the normal starting position.

An interior view of the primary control is shown with figure 20-13. This control device is is also equipped with a high-temperature-limit control. This control shuts down the heating plant whenever temperature of the furnace tends to become excessive. For example, if the thermostat were exposed to a blast of cold air for a long period of time, the heating plant may run long enough to become overheated to the point of damage or external fire if this high temperature-limit control were not used.

THERMOSTAT. — The thermostat is a temperature-sensitive device that responds to room temperature and indicates to the primary control, by making or breaking electrical contacts, that



1. Oil line to atomizing nozzle.
2. Igniters.
3. Deflector cone.
4. Atomizing nozzle.
5. Deflector blades.
6. Air-tube assembly.
7. Oil line from shut-off valve to air-tube assembly.
8. Air adjustment.
9. Blower.
10. Pump.
11. Pressure regulator valve.
12. Motor.
13. Ignition transformer
14. Adjustable leg.

54.127

Figure 20-10.—Pressure atomizing gun-type burner.

more or less heat is required. A typical room thermostat is shown in figure 20-14.

Operation of Oil Burner Controls

The oil burner primary or safety ignition control, with the aid of the thermostat and the limit control (fig. 20-11), controls the complete operation of the oil burner.

When the temperature in a heated space drops below that at which the thermostat is set, the contact points close; this, in turn, closes the starting contacts in the primary control, thus starting the ignition and motor. When the burner ignites properly, the sensing unit in the primary control is heated by hot gases and changes the circuit from the starting contacts in this control to the running contacts, thereby allowing continued operation of the burner. If the burner fails to ignite, the circuit in the primary control remains in the starting position for 90 seconds, after which the safety switch turns off the burner.

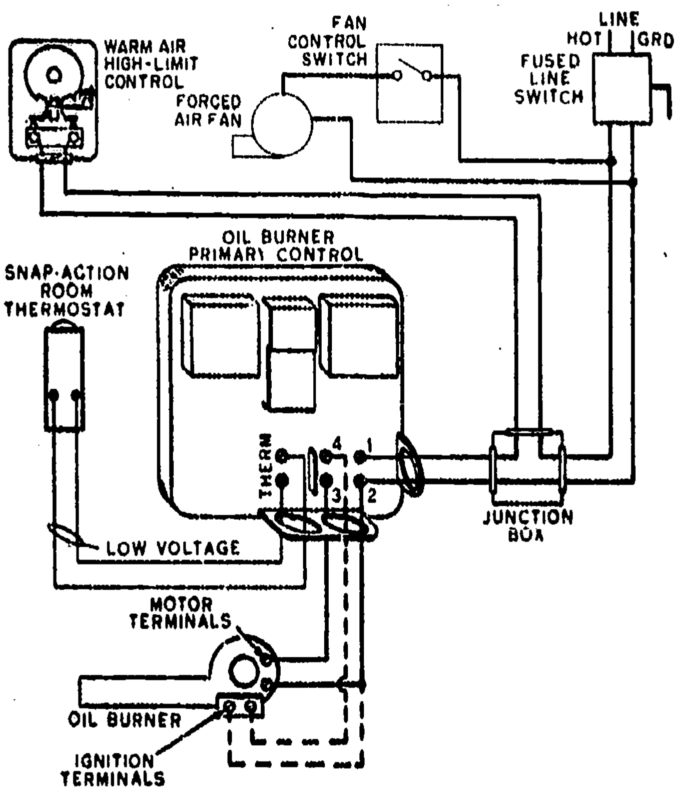


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Figure 20-11. — Typical forced warm-air control system.

After an ignition failure, the primary control locks out, and manual resetting is necessary to start the burner. However some controls permit two trials before locking out. If the primary control uses an intermittent ignition system, the ignition is on for a brief period of time when the burner starts, and is turned off when the control changes to the running circuit. With the constant ignition system, the ignition is on the entire period of burner operation. If the oil supply fails sometime after the burner has been operating, the sensing unit in the primary control cools and shuts off the burner. As a further safety measure, in the case of excessive furnace temperature, the high-temperature-limit switch is designed to shut down the heating plant.

When the temperature in the heated space rises above that at which the thermostat is set, the contacts in the thermostat open, thereby opening the contacts in the primary control and shutting down the burner.

Operation

Since the rate of heat production required to maintain desired temperature varies widely, means must be provided to control the rate at which heat is produced. This control may be operated manually or automatically. There are three generally accepted systems used in the operation of oil burners; they are the intermittent, high-low, and continuous systems.

In the INTERMITTENT system the burner operates at only one rate, a rather high one, until building temperatures are at the desired point, at which time automatic controls stop the burner completely until lower temperatures again cause it to resume operation. Automatic ignition of the electric or pilot-light type is essential to this system.

The HIGH-LOW system has two rates of burning, one below and the other above average demand. When building temperature falls below normal, the burner automatically starts to operate on high flame, changing to low flame when building temperature reaches a desired point.

In the CONTINUOUS system the flame burns continuously. The rate of burning, and therefore heat production, is regulated manually or automatically, however, to meet the demand for heat.

Flame Adjustment

After the burner has been visually adjusted and allowed to run about 30 minutes, reduce the stack draft until there is just enough over-fire draft in the firebox to keep pressure from increasing under unfavorable draft conditions. The draft regulator helps maintain a constant draft in the furnace regardless of outside weather conditions. Adjust the draft by properly setting the adjuster. Too little draft is likely to cause firebox pressure, odors in the building, and possible smoke or smothering of the flame. Too great draft accentuates the effect of a possible leak in the furnace, lowers the percentage of CO_2 in the flue gas, and in turn reduces the overall efficiency of the unit. After the burner flame and draft are properly adjusted, a flue-gas analysis should show a CO_2 content of approximately 10 percent. If it does not, recheck the burner-air adjustment and inspect for air leaks. For best results, the flame should be just large enough to heat the building properly in cold weather.

Air supplied to the burner will then be the minimum for clean combustion. If the furnace is large enough and the burner has been set for correct oil flow and minimum amount of air, stack temperature should not exceed 600° F. Higher stack temperatures indicate that the fire

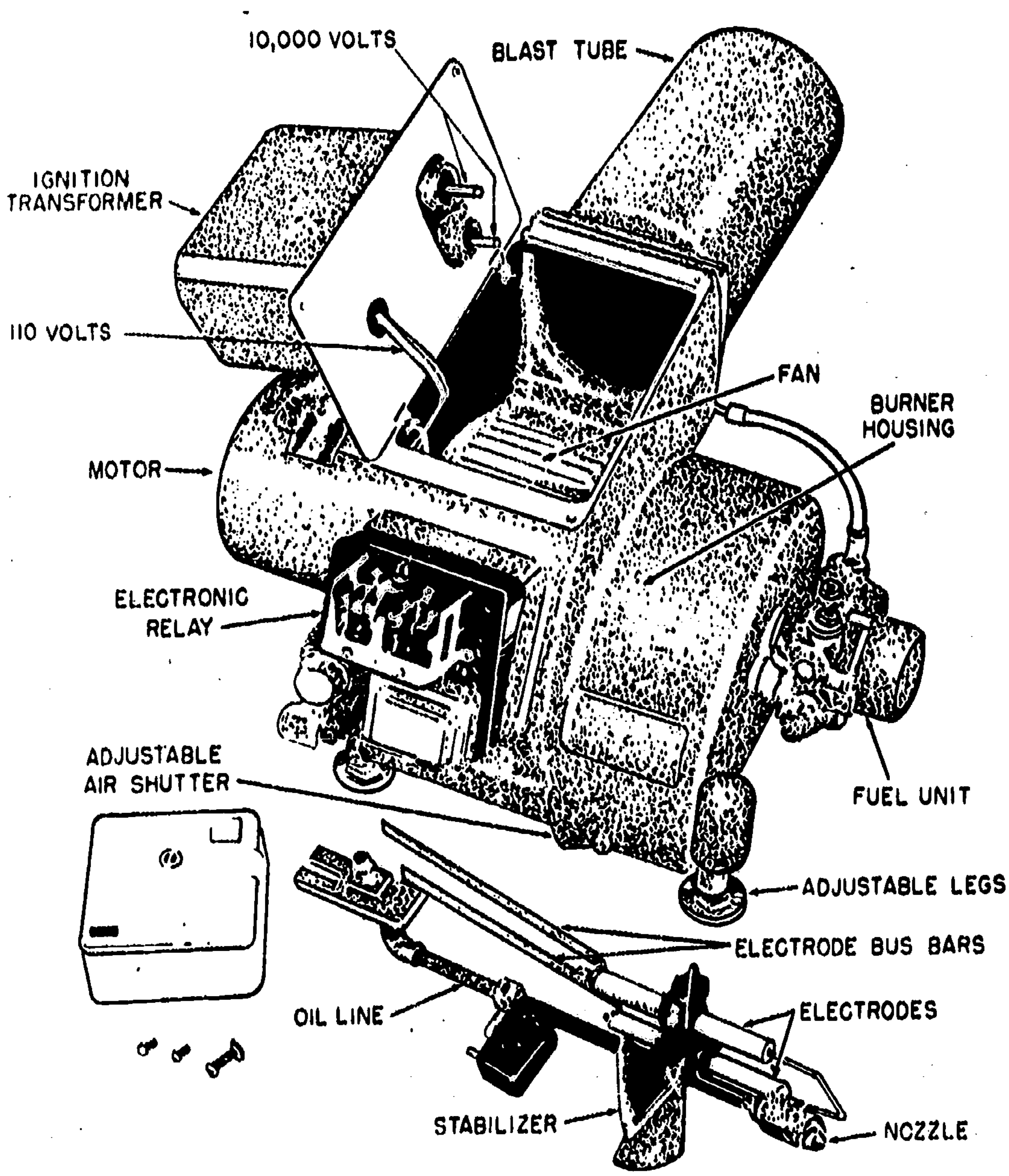

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Figure 20-12.—High-pressure gun-type oil burner.

is too large or the furnace too small, or that there is too much excess air.

Test Equipment

It is almost impossible to set and adjust a burner without instruments or test equipment. Proper instruments, in good working order, must be available in the heating shop for use by men who service this equipment.

The draft gage, usually of the pointer indicating type, is used to determine suction in the smokepipe or combustion chamber. Suction is measured in inches of water. Follow carefully the instructions for operating the instrument.

The stack thermometer is used to indicate the temperature of gases in the smokepipe. Insert the thermometer halfway between the center and outside of the smokepipe and not more than 12 inches from the furnace, between the smokepipe connection and the draft regulator or barometric damper. Be careful to prevent the thermometer from being influenced by cold air taken in by the draft regulator.

The flue-gas analyzer is used to determine the percentage of CO_2 produced by combustion.

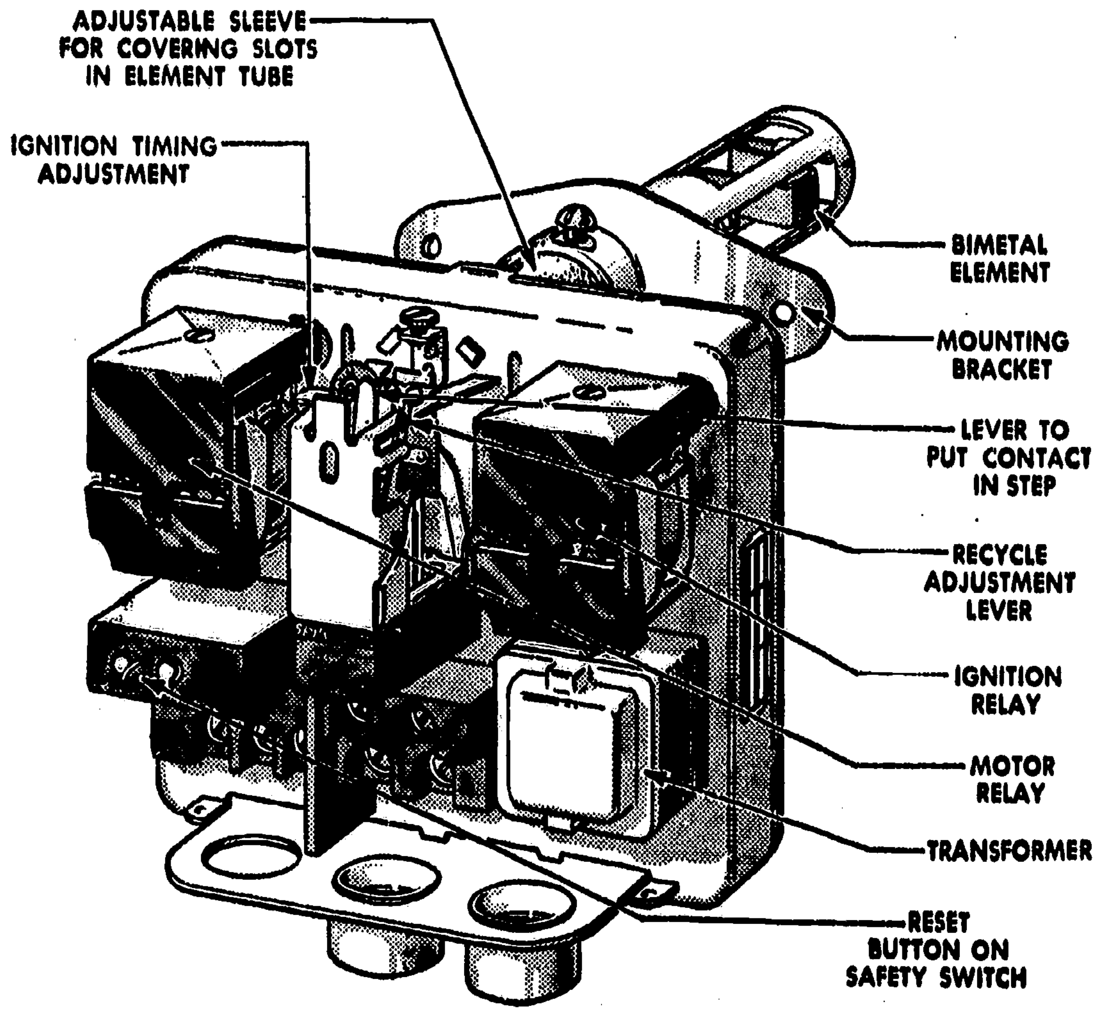

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Figure 20-13.—Interior view of a primary control.

The CO_2 reading shows how much excess air is being used, and with the stack temperature denotes approximately the efficiency of the furnace. If, despite a good flame setting, CO_2 readings are low, examine the furnace for air leaks.

Oil Burner Maintenance

Before attempting to start or to service oil burners, see that you have the proper maintenance equipment available. One item of equipment needed is a pressure gage set. This should consist of a 150-psi pressure gage, fittings to connect it, and a petcock for removing air from the oil line when starting the burner. You will need a full set of Allen setscrew wrenches for bypass plugs and for adjusting the nozzle holder and electrodes. Make sure you have a socket wrench of proper size for removing or replacing the nozzle, an open-end wrench as required for nozzle, holders, and a small thermostat wrench. This wrench comes packed with the thermostat and is used for adjusting the differential. A small screwdriver is required for adjusting pressure at the regulator and installing and servicing the thermostat. Another important item is pipe dope, and if available, use oil-line type only. If in doubt, order a can of special oil-pipe dope for use on all pipe threads requiring dope. A nozzle assortment should also be kept on hand. It is cheaper to make a change, time considered, than to clean the nozzle on the job. When a few nozzles have accumulated, clean them in the shop.

When installing a nozzle, use a socket wrench for turning the nozzle. Be sure the nozzle seat is clean. Screw it on until it reaches bottom, then back it off and retighten it several times to make sure of a tight oil seal. Do not tighten too much or the brass threads will deform making it difficult to remove the nozzle.

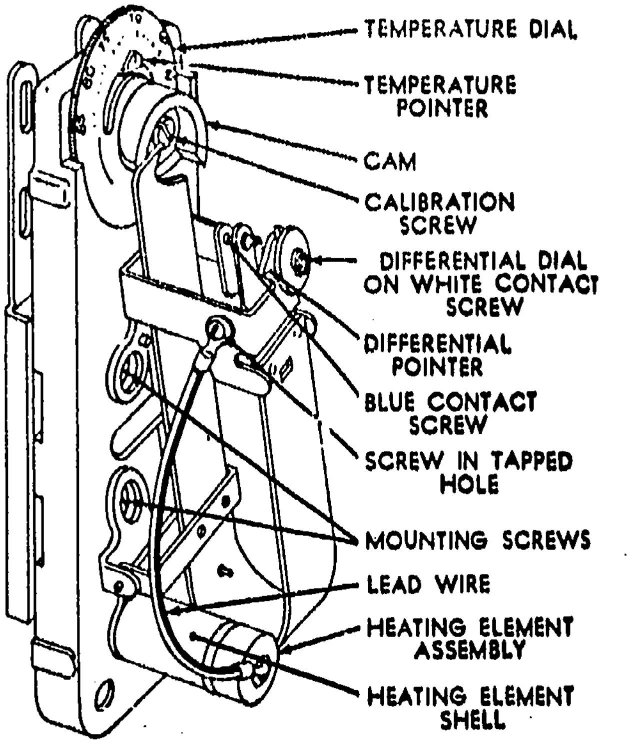

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Figure 20-14.—Room thermostat.

Clean the nozzles in the shop on a clean bench. A nozzle is a delicate device. Handle with care. Use kerosene or safety solvent to cut grease and gum, and use compressed air, if available, to blow dirt out. Use goggles for eye protection when blowing dirt out with compressed air. Never use a metal needle to clean the opening; it will ruin the nozzle. Sharpen the end of a match or use a nonmetallic brush bristle to clean the opening.

When checking the nozzle, adjustments may have to be made in the distance of the nozzle from the tube end, the distance of the ignition points ahead of and above the nozzle, and the distance or gap between the ignition points. Figure 20-15 illustrates these nozzles adjust ments. The nozzle tip is set 5/8 inch back from the tube end, ignition points set 1/8 inch apart, 1/8 inch ahead of the nozzle, and 1/2 inch above the nozzle centerline. These settings are given only for the purpose of illustration. Actual adjustments should always be made in accordance with the specific settings found in the manufacturer's instruction manual. Always tighten electrodes securely to ensure permanent adjustment.

When reinstalling either the pump or motor, check the coupling to ensure that there is no end pressure on the pump shaft as evidenced by lack of end play. If there is end pressure, the coupling should be loosened, moved closer to the pump, and retightened.

Troubleshooting

Common operating difficulties are methods of correcting them are outlined below.

A. If the FURNACE PULSATES on starting, on stopping, or during operation, check for—
   1. Proper adjustments of the nozzle-electrode assembly and blast tube in relation to each other and to the firebox.
   2. Improper draft. Make sure there is no down draft. Change the setting on the draft regulator if draft is not strong enough. Check the chimney to see that there are no leaks to cause poor draft.
   3. Defective nozzle. If found defective, install a new nozzle.
   4. Air in the line between the fuel unit and the nozzle. Air trapped here will be compressed during burner operation and will expand when the burner stops, causing oil to squirt out of the nozzle, accompanied by a bubbling sound. Waiting a few days to make final adjustments often allows time for trapped air to escape.

B. If the FLAME IS RAW AND STRINGY, check for—
   1. Too great an opening in air adjustment. Adjust volume of air.
   2. Partly plugged nozzle. Install new nozzle.
   3. Air in pump. If pump contains air, vent with petcock on pressure gage.

C. If the IGNITION POINTS COLLECT CARBON, check for—
   1. Ignition points too close to nozzle. Adjust.
   2. Nozzle loose in holder. Tighten nozzle.
   3. Improper oil cutoff when burner is shut down. Check pressure-regulating valve, and clean if necessary.

D. If the OIL PUMP IS NOISY, check for—
   1. Air in the oil line. (This is the most common cause.) Remove air by loosening vent plug where pressure gage is attached.

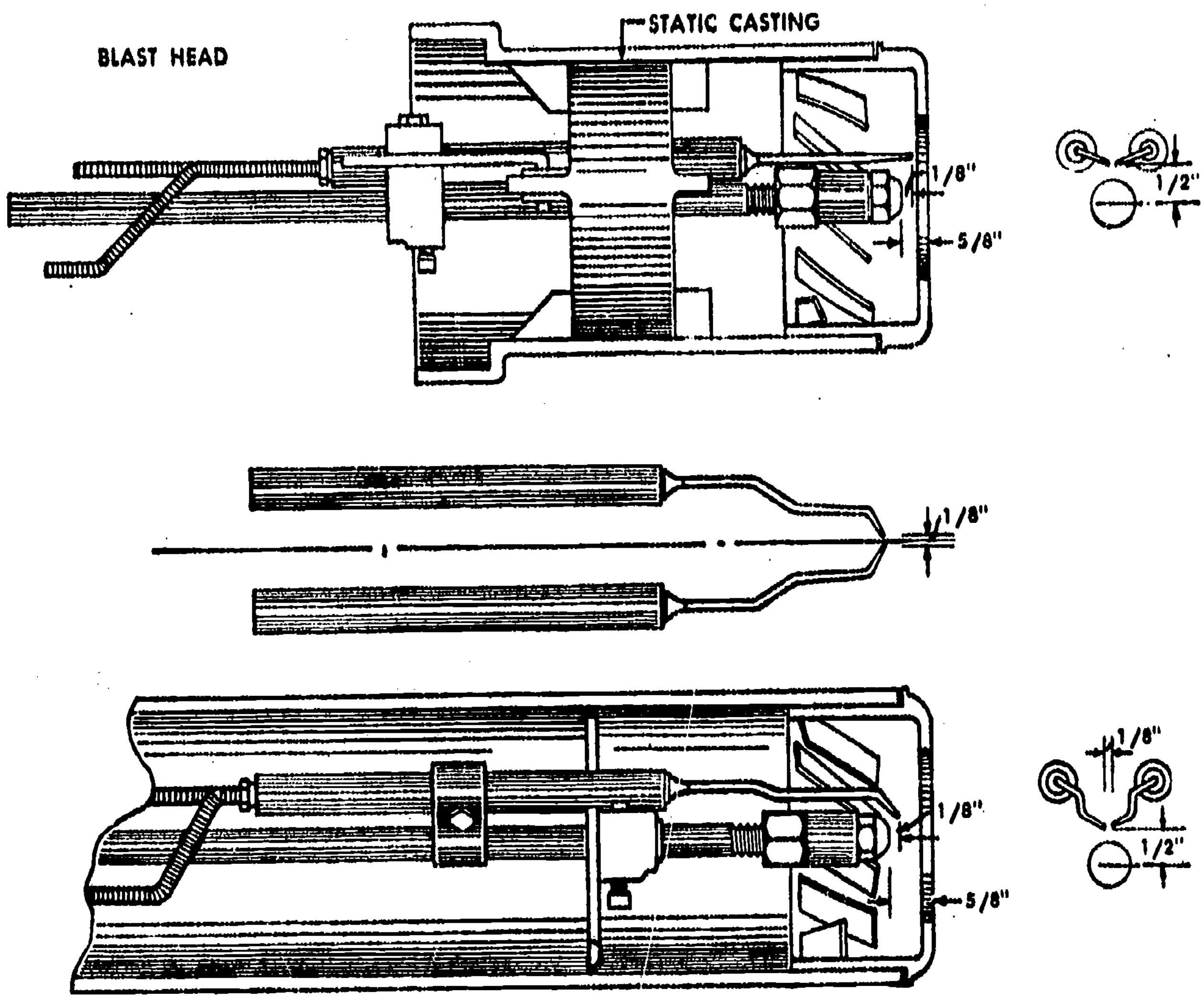

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Figure 20-15. —Settings of ignition points and nozzle.

2. Leaks in suction line. Any leak in overhead piping above liquid level in storage tank allows air to suck into oil line.
3. Excessive suction on oil line, due to a plugged strainer or to water condensed in oil tank. Clean or change filter, or drain or siphon water from tank, or both.

E. If the BURNER STARTS AND STOPS TOO FREQUENTLY, check for—

1. Thermostat improperly wired. Be sure that thermal element in room thermostat is screwed in tight. Check wiring, to determine whether wires are reversed or spliced in correctly.
2. Thermostat not properly adjusted. Adjust in accordance with instructions packed with thermostat.
3. Drive-arm adjustment incorrect. Check primary control or stack switch in accordance with instructions packed with unit.
4. Limit control set too low. This will shut burner off before building can get warm.
5. Plugged air filters which cut off air circulation. This condition will cause burner to shut down on limit control. Change or clean the filters.
6. Nozzle too large for unit, so heat buildup is too rapid. Install nozzle of correct size.

F. If the BURNER FAILS SAFE (stack control has thrown the burner safety shutdown), check for—

1. Low voltage occurring at night. Check with a recording voltmeter for at least 24 hours and preferably longer.

2. Wrong polarity of wiring. If hot line is connected where ground should be, there is sometimes enough leakage through the control to cause a safety shutdown.
3. Primary control or stack switch improperly adjusted. Check all adjustments within this control in accordance with instruction sheet.

G. If there is NO OIL AT THE NOZZLE, check for—
1. Fuel too low in supply tank.
2. Plugged nozzle. Install new nozzle.
3. Leak in suction line. Repair.
4. Leak in vacuum-gage port. Repair.
5. Pump failing to turn. Check motor, fuses, overload switch, wiring, and controls.
6. Leaking strainer gasket. Install new gasket.
7. Leaking pump-shaft seal. Install new seal.
8. Fuel unit not operating. Loosen vent plug in fuel unit (dump) and see whether fuel is being delivered that far. If fuel is not being delivered at fuel unit, return it to shop for repair.

Oil-Tank Installation

Tank installation is largely governed by local conditions. Listed here are the principles of tank installation that give greatest freedom from service problems. Adhere as closely to these recommendations as local conditions permit.

When possible, install single-pipe gravity oil feed in inside tanks or elevated outside tanks. (See fig. 20-16.) This type installation is used for single-stage pumps. Use a 1/4-inch globe valve at the tank instead of a larger size. Larger valves sometimes cause tank hum.

For all installations use a continuous piece of 1/2-inch copper tubing from the oil tank or valve to the burner and a similar piece for the return when required. The principle is to minimize the number of joints and thus minimize the possibility of air or oil leaks.

For inside installations where it is necessary to run the piping overhead between the tank and burner, when the burner is either above or below the tank level, the two-pipe system is recommended. This requires the use of a two-stage pump.

A dual-stage pump may be changed from a single-stage to a two-stage pump to accomodate a single pipe or two pipe system. The stages on a Webster fuel pump can be changed by removing the four screws on the pressure side of the pump, and lining the number one up with the "P" on the pump body for a one pipe system. The number two lined up with the "P" is for a two pipe system. Most Sunstrand fuel pumps are shipped from the factory set up for a one pipe system. To change to a two pipe

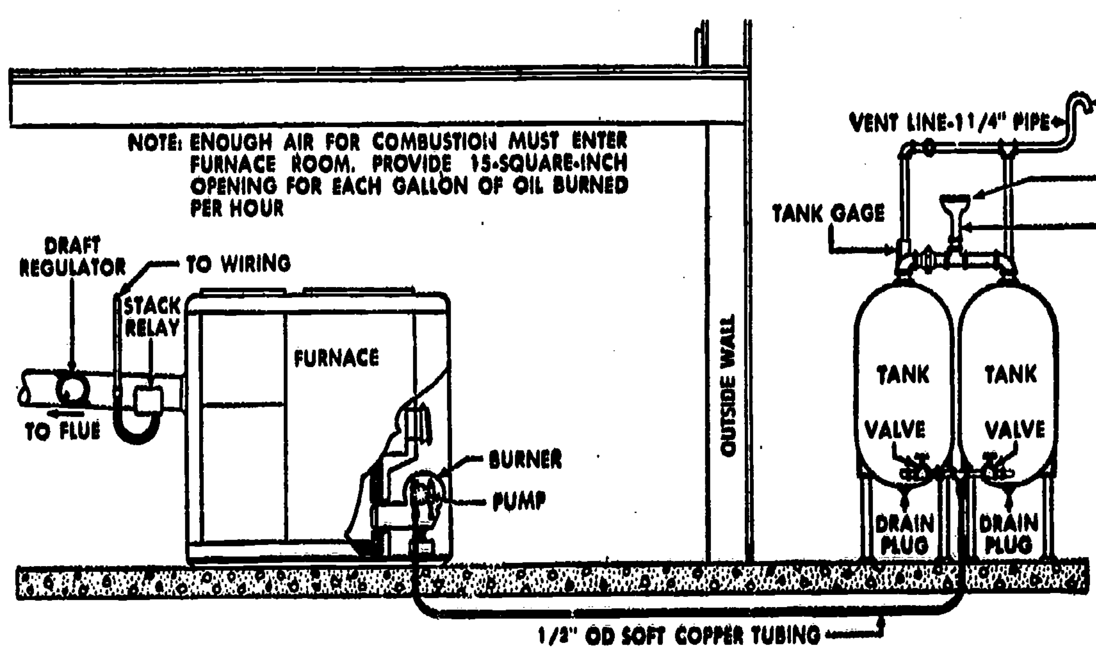

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Figure 20-16.—Diagram of piping for inside or outside elevated tank installations.

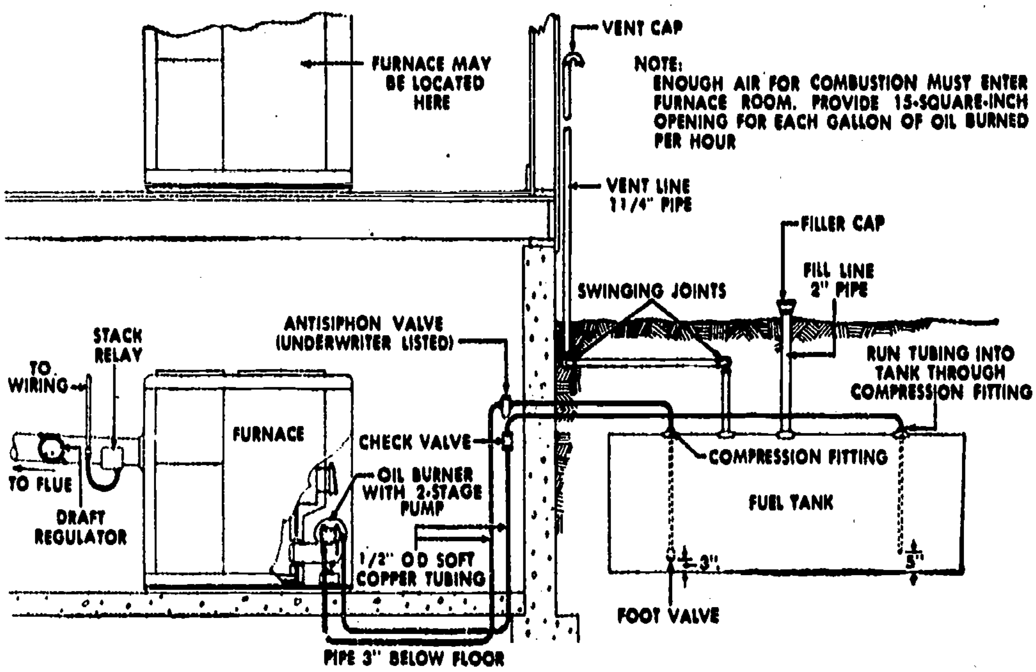

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Figure 20-17. — Diagram of piping for buried outside tank.

system remove the 3/8-inch pipe plug from the bottom of the pump housing. There you will find an Allen head plug. Remove this plug for a two pipe system.

Install outside tanks (fig. 20-17) according to the instructions below.

Normally, when installing an underground fuel tank, the suction and return lines are black iron from the tank to the inside of the building and there the burner is connected by copper tubing with a coil in it (not shown in the illustration) to eliminate vibration.

The return line is usually installed in the opposite end of the tank. Carry it to within 5 inches of the bottom. This creates an oil seal in the two lines and any agitation caused by return oil is safely away from the suction line.

A 1 1/2-inch fill line and a 1 1/2-inch vent line are recommended. Carry the vent well above ground and put a weatherproof cap on it. Pitch the vent line down toward the tank.

Use special pipe dope on all iron pipe fittings that carry oil.

Treat the underground outside tank and piping with a standard commercial corrosion resistant paint or preparation.

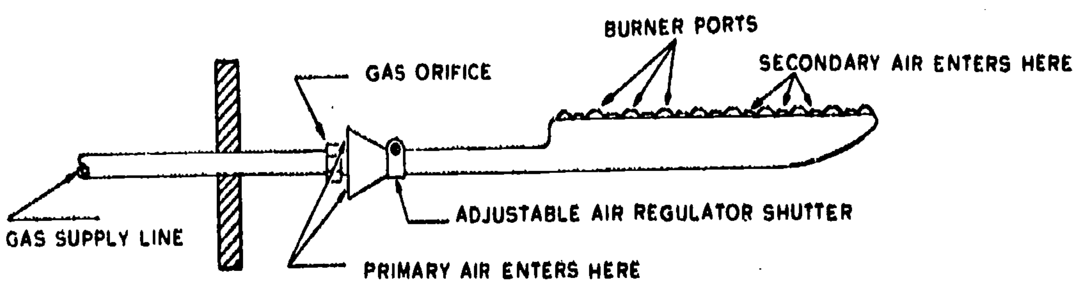

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Figure 20-18. — The Bunsen-type burner.

GAS BURNERS

To use natural gas, a nearly ideal fuel, requires comparatively simple equipment and unskilled labor. This gas is almost free of noncombustibles and is therefore clean. However, it is relatively dangerous compared to coal or oil because it mixes easily with air and burns readily. Extreme care must be exercised to prevent or stop any leakage of gas into an unlighted furnace or into the boiler room. All gas burners should be approved by the American Gas Association and installed in accordance with the standards of the National Board of Fire Underwriters.

The gas burners used in gas-fired furnaces usually have a nonluminous flame and are the Bunsen-type as illustrated in figure 20-18. Part of the air needed for combustion is primary air that is drawn into the burner mixing tube or venturi, where it mixes with the gas which burns at the burner's ports. The secondary air is supplied around the base of each separate burner flame by natural draft or is induced by a draft fan.

Gas Burner Controls

The gas burner controls include the following units: Manual gas valve, solenoid gas valves, gas pressure regulator, pilot light, thermocouple, thermocouple control relay, and limit control. (See figure 20-19.) A manual gas cock or valve must be installed ahead of all the controls.

MANUAL GAS VALVE. — The manual gas valve is installed on the heating unit next to the gas pressure regulator. It is used to shut off the gas to the heating unit in case some of the controls must be repaired or replaced.

PRESSURE REGULATOR. — The gas pressure regulators used in domestic gas-heating systems are usually of the diaphragm type, like those illustrated in figures 20-19 and 20-20. A gas pressure regulator maintains the desired pressure in the burner as long as the gas main pressure is above the desired pressure. When gas pressure to the burner is low, the pressure regulating spring (see fig. 20-20) pushes the diaphragm down in turn pushing the pilot valve down. When the pilot valve opens, supply pressure is applied to the top of the operating piston. As the operating piston moves down, the main valve opens admitting supply pressure to the burner. As burner pressure rises, the diaphragm is pushed up against the pressure regulating spring closing the pilot valve. This removes the supply pressure from the top of the operating

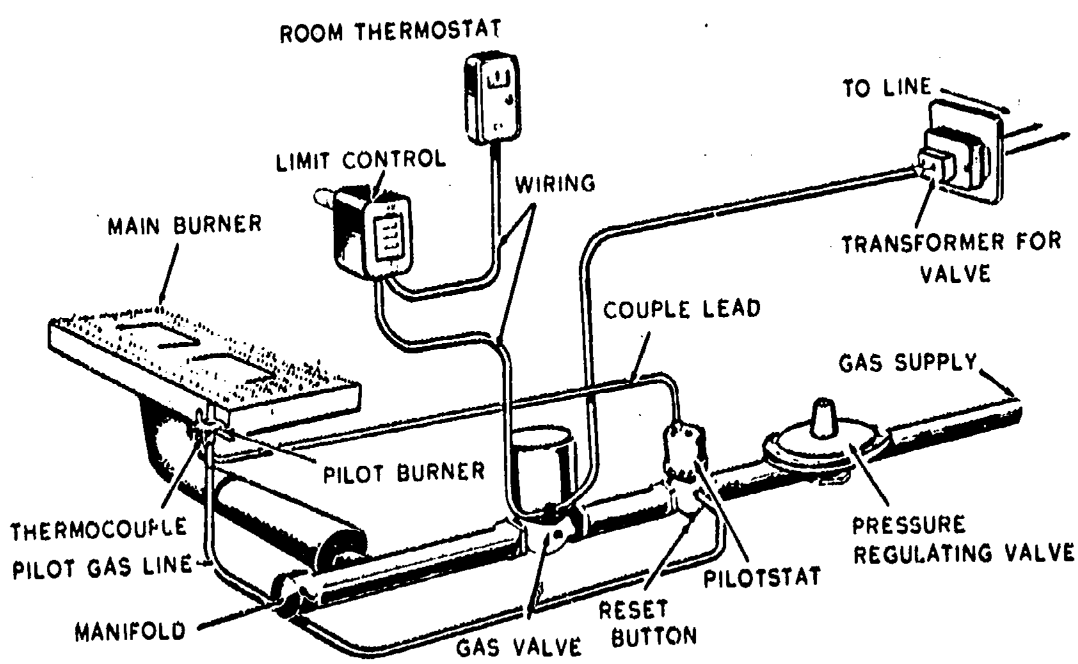

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Figure 20-19. — An automatic gas burner control system.

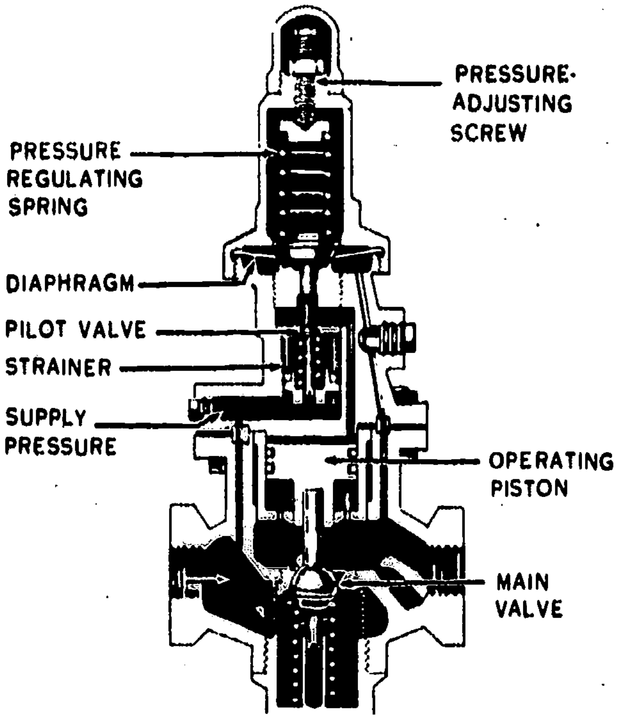

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Figure 20-20. —A gas pressure regulator.

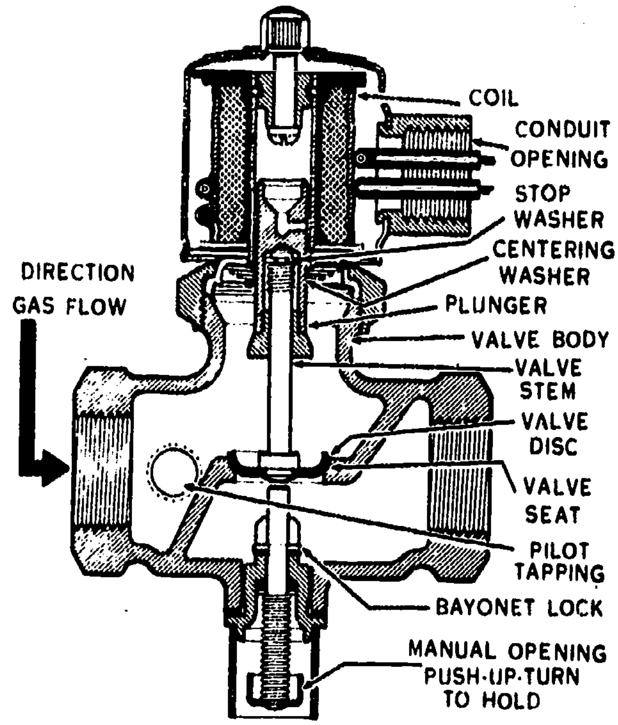

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Figure 20-21. —A standard gas solenoid valve.

piston and the piston return spring pushes the piston up closing the main valve. The regulator is thus closed every time the burner pressure gets above the desired amount. The setting of the regulator can be varied by turning the adjusting screw located at the top of it.

SOLENOID GAS VALVE. —The basic principles of construction and operation applied in all solenoid gas valves are similar. However, the design of each individual unit differs somewhat from the others. The two most common types of solenoid gas valves are the standard solenoid valve and the recycling solenoid valve discussed in the following paragraphs.

The STANDARD SOLENOID GAS VALVE shown in figure 20-21 is of the electric type. It is suitable for use with gas furnaces, steam and hot water boilers, conversion burners, and industrial furnaces. This valve operates when a thermostat, limit control, or other device closes a circuit to energize the coil. The energized coil operates a plunger, causing the valve to open. When there is a current failure the valve automatically closes, due to the force of gravity on the plunger and valve stem. The gas pressure in the line holds the valve disk upon its seat. To open this valve during current failure it is necessary to use the manual opening device at the bottom of the valve. When the electric power is resumed, you place the manual opening device in its former position.

The RECYCLING SOLENOID GAS VALVE illustrated in figure 20-22 can be used with the same heating equipment as the standard solenoid gas valve. The design of this valve differs from that of the standard solenoid gas valve in that it is equipped with an automatic recycling device which allows the valve to switch to manual operation during power failure. However, upon the resumption of the power, the thermostat automatically resumes control of this valve.

DIAPHRAGM VALVE. —The diaphragm gas valve illustrated in figure 20-23 can be used interchangeably with a solenoid gas valve. Its main feature is the absence of valve noise when it is opening or closing. In this type of diaphragm valve, the relay energizes and opens the three-way valve, so that the gas pressure on the top of the diaphragm is released to the atmosphere. Reducing the pressure on the top of the diaphragm in this manner causes the gas supply pressure to flex to diaphragm upward opening the main gas valve. When the relay is deenergized, the vent to the atmosphere is sealed and pressure from the

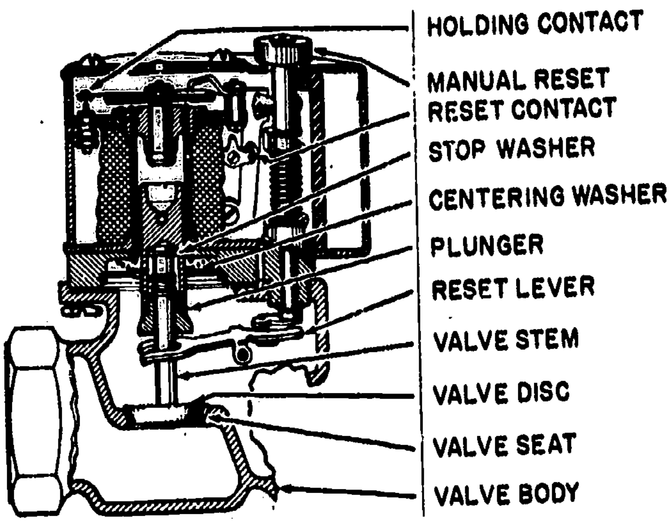

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Figure 20-22.—A recycling solenoid valve.

gas supply is allowed to be applied to the top of the diaphragm, forcing it down and sealing the main valve.

PILOT LIGHT.—The gas pilot light in a gas heating unit is a small continuous-burning flame that lights the main burner during normal operation of the heating unit. It is located near the main burner as shown in figure 20-19.

The gas flow to the pilot light is, in some cases, supplied by a small, manually-operated gas shutoff valve located on the main gas line above the main gas valve. In other cases, the gas can be supplied from the pilot tapping on a solenoid gas valve, as shown in figure 20-21. In more expensive heating units, the gas for the pilot light is often supplied by a thermocouple-controlled relay.

THERMOCOUPLE.—A thermocouple is probably the simplest unit in the electrical field which is used to produce electric current by means of heat. It is constructed of two U-shaped conductors of unlike metals in the form of circuit, as shown in figure 20-24. Suppose that these conductors were composed of copper and nickel, respectively, and joined as shown in the figure; then two junctions between the metals would exist. If one of these junctions were heated by a flame, a weak electric current would be produced in the circuit of these conductors. A series of junctions can be arranged to form a thermopile to increase the amount of current produced, as shown in figure 20-25.

In the heating field, thermocouples and thermopiles are employed to produce the electrical current used to operate such units as gas valves, relays, and other safety devices.

The thermocouple is located next to the pilot light of the main gas burner, as shown in figure

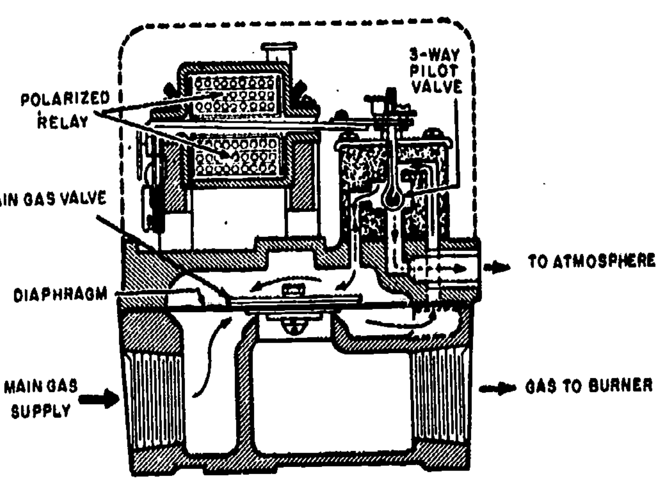

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Figure 20-23.—A diaphragm gas valve.

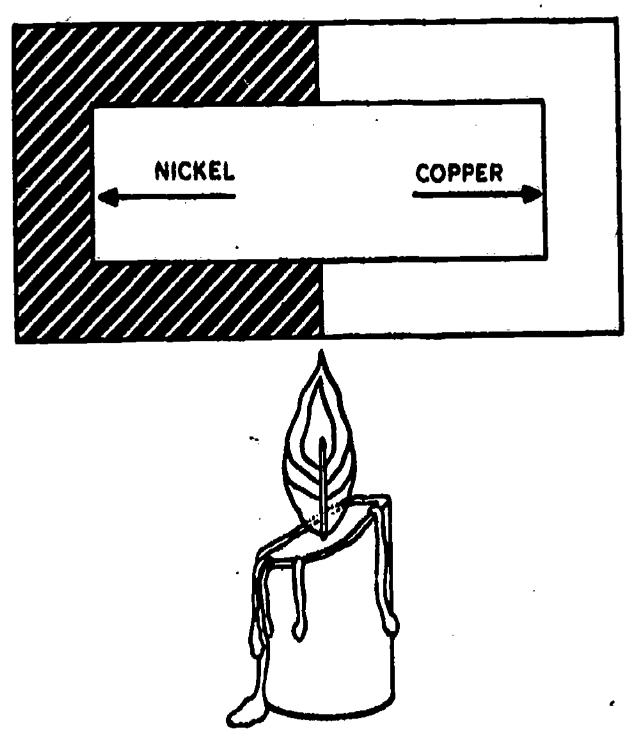

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Figure 20-24.—The principle of a thermocouple.

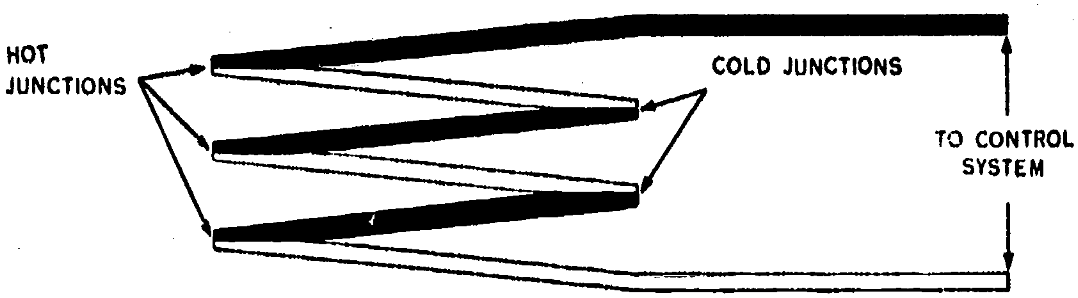

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Figure 20-25. — A thermopile.

20-19. It generates the electric current which holds open a main gas valve, a relay, or any other safety devices, permitting gas to flow to the main burner. Soon after the pilot light is extinguished, current ceases to flow to these safety devices, thus causing them to shut off the gas to the heating unit. These safety devices will not operate again until the pilot light is lighted and current is again generated by the thermocouple.

THERMOCOUPLE CONTROL RELAY.—The thermocouple-operated relay, shown in figure 20-26, is a safety device used on gas-fired heating equipment. The thermocouple, when placed in the gas pilot flame, generates electricity. The electric current energizes an electromagnet that will hold a switch or valve in the open position as long as the pilot flame is burning. When the pilot flame goes out, because of high drafts or fuel failure, the electromagnet will be deenergized, thus closing and preventing the opening of the switch or valve. The closing of the valve or switch prevents the burner from filling the combustion chamber with unburned gases.

To relight the pilot light, it is necessary to push up the reset button at the bottom of the relay and allow the gas to flow to the pilot light. Since some heating units are not equipped with relays, the pilot light is not automatically shut off in case of gas supply failure.

The diagram illustrated in figure 20-27 is an electrical switch-type relay. It is entirely electrical and can be used as controlling unit for either the magnetic or diaphragm gas valves. This unit is also actuated by the electric current generated by the thermocouple, and it controls the operation of the gas valve in the magnetic and diaphragm valves. A relay of this type must also be reset manually for normal operation.

LIMIT CONTROL. — The limit control in a gas burner system is a safety device. It shuts off the gas supply when the temperature inside the heating unit becomes excessive. The limit control device can be adjusted to the desired setting. It excercises direct control on the gas or diaphragm valve.

FURNACE INSTALLATION

Since there are many types and makes of oil- and gas-fired warm-air furnaces on the market,

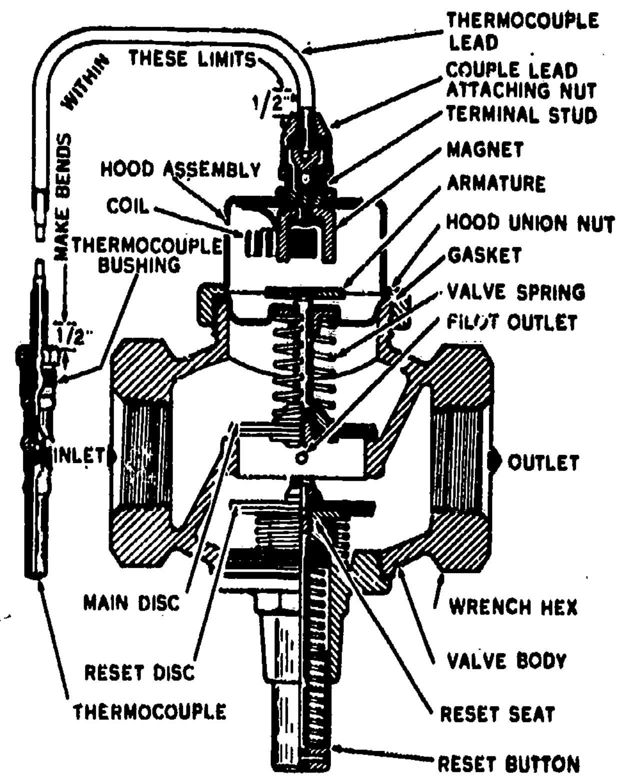

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Figure 20-26. — A typical thermocouple and valve relay assembly.

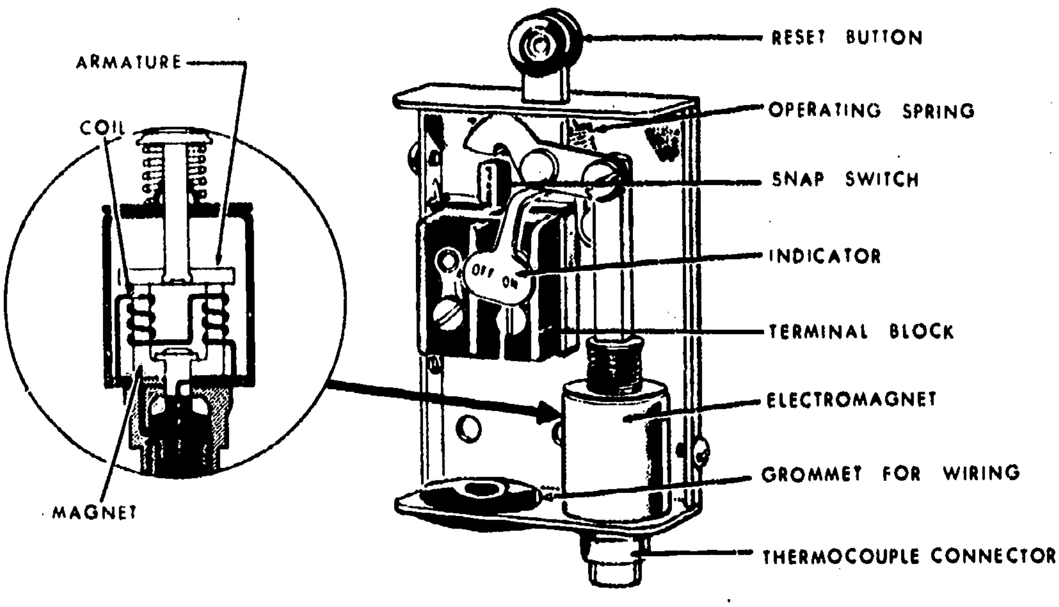

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Figure 20-27.—An electric switch-type relay.

detailed assembly instructions to suit all makes and types cannot be given in this manual. However, some general instructions, which apply to both oil-fired and gas-fired furnaces except as noted, are given below.

Carefully follow assembly instructions included with each furnace or blower shipment. Each piece or casting is manufactured to fit in its proper place. Parts are seldom interchangeable.

Install furnaces in a level position. If the floor is uneven, use steel or cast-iron wedges, or the leveling bolts provided on some equipment. Use a spirit level to make sure the unit is level.

Set gas-fired and oil-fired forced-air units which have the blower below the heating element or combustion chamber on masonry which is at least 3 inches thick and extends at least 12 inches beyond the casing walls. Install all other units on a solid masonry floor. Provide enough clearance to permit easy access for repairs. Make the clearance at least 18 inches from wood or other combustible material, unless you install an asbestos board at least 1 inch from the combustible material. Units may be installed nearer to masonry walls; however, leave ample room to permit proper servicing.

Furnace cement is furnished with each cast-iron furance. Seal all furnace joints with a liberal amount of furnace cement between sections to ensure that the furnace is gastight. Asbestos rope is furnished with a number of furnaces; follow the manufacturer's instructions covering its use. See that projections from the furnace such as the smokepipe or cleanout doors extend through the outside of the casing.

In assembling a furnace, exercise care in tightening all bolts. Draw each bolt until it is almost tight. Then, after all bolts have been installed, draw each one gradually until all are uniformly and properly tight. Avoid drawing bolts too tight, as this will crack or break a casting or buckle a steel plate.

After assembling the furnace, check all doors for free operation and tight fit.

Install the down-draft diverters furnished with the equipment on all gas-burning furnaces. Diverters are developed for individual furnaces.

Use vent or smokepipe which is at least as large as the smokepipe outlet of the furnace. Securely fasten the vent or smokepipe at each joint with a minimum of three sheet-metal screws. Install horizontal pipe with a pitch upward of at least 1 inch per linear foot. (See fig. 20-28.)

Ventilate the furnace room adequately to supply air for combustion. Provide an opening having 1 square inch of free air area for each 1000 Btu per hour of furnace input rating with a minimum of 200 square inches. Locate the

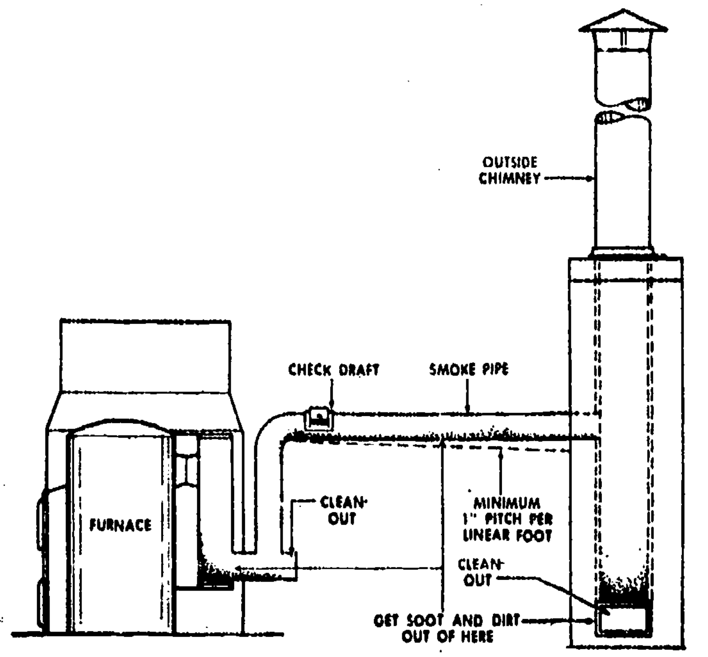

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Figure 20-28. — Typical smokepipe installation.

opening at or near the floor line whenever possible. In addition, provide two louvered openings, each having a free air area of at least 200 square inches in it, at, or near the ceiling as near opposite ends of the furnace room as possible.

Most blowers are furnished complete with blower, motor, motor base, filter rack, and complete housing. If a base consisting of a sheet-metal bottom is furnished, follow the manufacturer's instructions for assembling the unit. If a housing without a sheet-metal bottom is furnished, fasten the blower and motor base securely to a masonry floor with lag bolts and expansion shields. Exercise care in locating the motor and blower and getting them in true alignment. Allow enough distance between the motor and blower to permit belt adjustment. If only the motor and blower are supplied, fabricate a cabinet so that it has ample space for proper air movement. Provide doors and openings to permit oiling, adjustment, and minor repairs to the motor and blower. If a sheet-metal bottom is not installed, fasten the blower casing to a masonry floor and grout it to prevent air leakage at that point. Install an asbestos-cloth collar in the casing to fit snugly around the blower outlet and eliminate vibration noises from the blower. Connect the blower casing and blower boot with the same type of connection as that between the boot and the furnace casing.

GENERAL FURNACE OPERATING AND MAINTENANCE INSTRUCTIONS

The motor pulley is usually adjustable for a wide range of speeds. Adjust the speed of the blower to deliver the volume of air called for in the specifications. However, if this has been done and a change of blower speed is required, make the change by adjusting the motor pulley, then resetting the belt tension. A simple way to determine the proper volume of air is to hold a handkerchief at the top of the warm-air outlet and let the moving air raise it. Velocity should be such that the handkerchief is blown almost horizontal.

To adjust the motor pulley, loosen the setscrew (fig. 20-29) and separate the two pulley faces to decrease blower speed. Bring the faces closer together to increase speed. In locking the pulley adjustment with the setscrew, be sure to force the setscrew down on the flat surface of the pulley shaft and not on the threads.

To adjust belt tension, slide the motor on its base. Every blower motor has a means of making the tension adjustment. Unless a manufacturer specifically recommends a tighter adjustment, leave from 1 1/2 to 2 1/2 inches up-and-down slack in the loose side of the belt, depending on its length. (See fig. 20-29.) If a V-belt is adjusted too tight, it will wear rapidly and seriously overload the motor. If it is too loose, it will slip.

Check the motor-pulley and blower alignment on each installation, using a straight edge or tight line. The motor shaft is usually long enough to allow for this adjustment. However, if the alignment adjustment cannot be made by this method, move the motor into the proper position.

Most blowers have bearings that are self-aligning. Some, however, have bearings that are held in alignment by bolts that anchor the bearings to the blower. If of this type, check bearing alignment; if bearings are binding, loosen bolts, bring bearings into alignment, then retighten bolts.

Thrust collars are locked to the shaft on each side of one of the blower bearings. These collars keep the blower wheel in alignment and, when properly set, eliminate end play.

If a thumping noise occurs in the blower, there is too much end play. This noise may be eliminated by setting the thrust collars closer. Exercise care to set collars as closely as possible

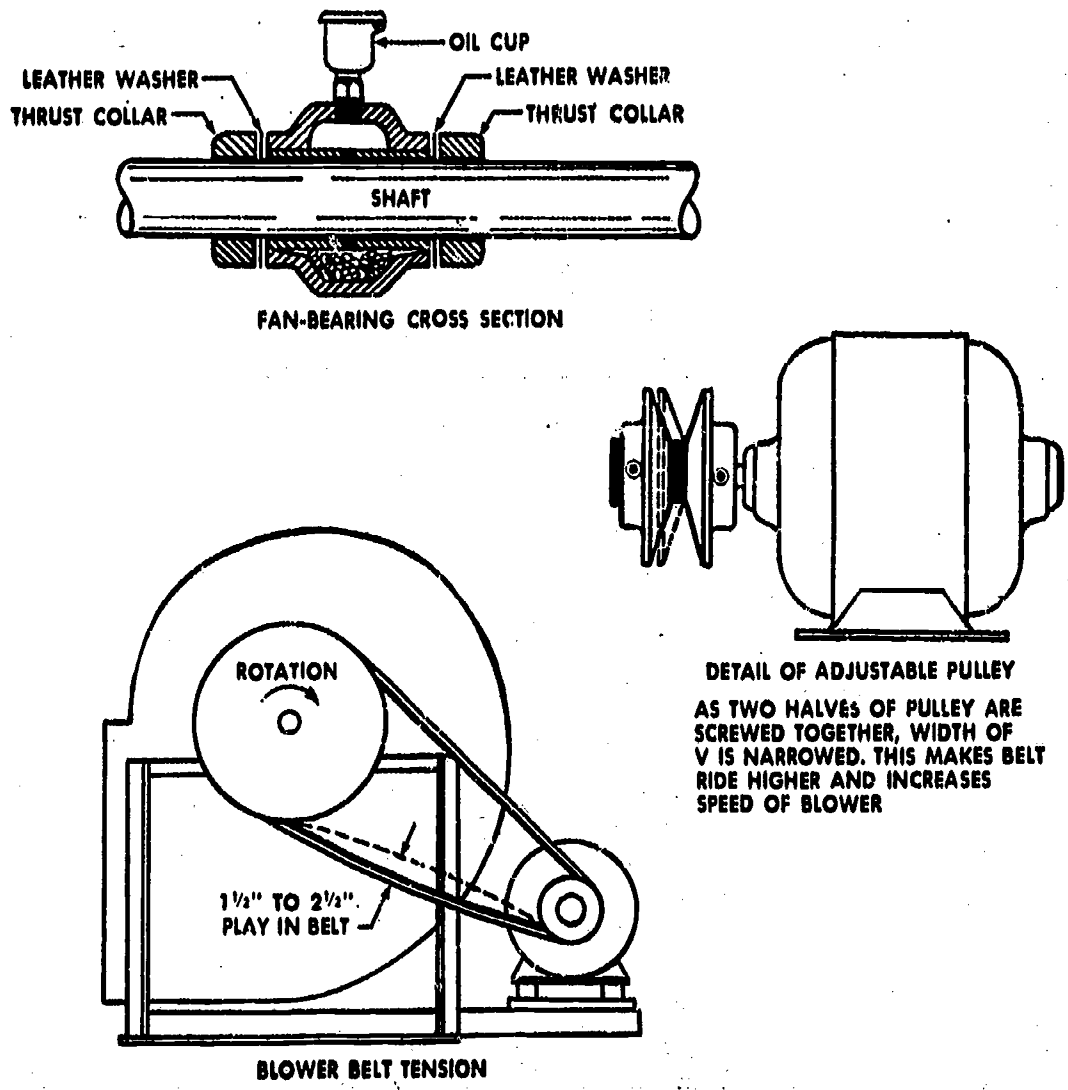

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Figure 20-29.—Bearing, pulley, and belt adjustments.

without binding. With either type of bearing, remove the belt and rotate the blower wheel to be sure it rolls freely.

Oil the motor and blower bearings when the unit is placed in service, and every 3 months during the heating season. Use thin wire, such as a straightened paper clip, to open the oil passage to the shafts at each oiling.

Dirty filters impede air circulation, regardless of blower speed. If little or no air passes over the furnace, the building will be insufficiently heated, and the furnace will overheat, which may result in serious damage. Inspect filters at least once each week. For replaceable type filters, if dirt is deposited so thickly that air circulation is obviously impaired, replace filters. If new filters are not immediately available, remove one or two filters from the blower so air can be circulated until clean filters are available.

Another method of finding whether filters are dirty enough to require replacement is to remove enough filters to give the return air full-rated square-inch capacity and check the amount of air coming from warm-air openings. If the amount of warm air has increased very noticeably, filters are dirty and require replacement.

Most humidifiers used in warm-air installations are the pan type with a float to regulate the water level. (See fig. 20-9.) Because of the high temperature to which the float valve is subjected, it frequently sticks in an open or closed position. To release the valve, move the float ball up and down to allow water pressure to clean the dirt or other accumulation from the seat. Frequent jiggling of this float control will prevent sticking. If water is comparatively free of solids, the humidifier float seldom requires service. If the water condition is bad, however, considerable difficulty may arise. It is of prime importance to check the installation of the pan to see that it does not overflow on the combustion chamber or radiator of the furnace.

Install the blower and limit controls in the top of the casing and in the opening provided by the manufacturer. If the opening has not been provided for this control, install it 10 to 18 inches above the top of the combustion chamber and in a location that is easily accessible for inspection and adjustment.

Set the blower control to stop the blower at between 80° and 90° F in the plenum chamber. Adjust the control to start the blower at 115° for gas or oil. The blower should run continuously when outside temperature is 35° or below. The more continuously the blower runs the better the building will be heated, particularly in cold weather. Slightly higher temperature setting may be used in cold climates, or where a long duct is installed, or to meet some other local condition. Keep deviation from settings recommended above to a minimum.

Set the limit control to turn off the fire at 175° in milder climates and 200° in colder climates. Never set the limit control any higher than necessary to keep the building at proper temperature. Set the limit cutoff point low in mild weather and raise it somewhat as the weather gets colder.

FURNACE TROUBLESHOOTING

A. IF NOT ENOUGH HEAT IS SUPPLIED, check for—

1. Filters plugged with dirt. Clean or remove as instructed.

2. Blower running too slowly on account of adjustment of motor pulley or slipping of belt. Adjust speed or tighten belt.

3. Blower not operating on account of a blown fuse or an overload that would stop motor automatically. Most motors have an automatic overload protecting switch. If the belt is too tight causing excessive pressure on bearings, or thrust collars bind, the motor will be overloaded and the overload switch will throw the motor off. Except where the overload switch has a manual reset, the motor will start again when the motor has cooled sufficiently for the automatic switch to complete the electrical circuit, but will again shut off if an overload still exists. In larger motors the overload switch is in a separate box. To start the motor again, push the reset button in this overload switch. Whenever the motor is found to be cutting out because of an overload, eliminate the overload before continuing operation of the motor. If the fuse is blown out, replace it.

4. Blower running in wrong direction. If a blower is running backwards, a small amount of air will go forward to the system. Correct the trouble by connecting internal leads of the motor according to the manufacturer's instructions.

5. Dampers in air ducts closed, or partly closed, so air circulation is impeded. Frequently handles have been removed from inside duct dampers and the position for these dampers cannot be determined without checking through a small opening made in the duct for that purpose. If this condition exists, check the position of dampers, and replace handles if available.

B. IF ROOMS ARE FIRST HOT, THEN COLD, check for—

1. Blower control set too high, so blower does not start until the furnace is very hot, and a surplus of heat is then blown into the building. Set the blower control down in accordance with recommendations for blower control settings. To test for this condition, turn on the manual switch controlling the blower and permit the blower to operate continuously regardless of plenum chamber temperature. If this relieves the condition, the blower control is set too high. Lower the temperature setting suitably.

2. Room thermostat out of adjustment, allowing too great a temperature difference between the time when the thermostat makes contact to call for heat and when it breaks contact to close down the fire. Adjust the thermostat in accordance with the manufacturer's recommendations.

3. Limit control set too high. Adjust control.

C. IN CASE OF A COLD DRAFT ON THE FLOOR, check for—

1. A window or door open or large cracks or loose-fitting windows admitting an excessive amount of cold air. Close the door or window, tighten loose-fitting windows, and seal cracks.

2. Filters plugged so insufficient air is delivered. In this case, air that does come from the furnace into the room will be very hot. This will cause air at the floor line to be cold because it is not being drawn off the floor into the furnace fast enough. Clean or replace filters.

3. Blower control set too high. Adjust control.

D. IF THE BLOWER CONTROL FAILS TO WORK, check operation of the contacts. If the control fails to make or break contact properly, it has probably been ruined by overheating of the furnace. However, the control may have been tampered with by unauthorized personnel. Install a new control. Do not operate a forced-warm-air furnace without a blower control.

E. IF THE LIMIT CONTROL FAILS TO WORK, check operation of the contacts. Reason for failure of this control is the same as that for the blower control. If new controls are not immediately available, temporary heat can be obtained by wiring across the blower- and limit-control terminals in suitable manner to operate the blower continuously. Use this method ONLY IN AN EMERGENCY.

F. IF THE BLOWER STARTS AND STOPS TOO FREQUENTLY, check the settings of the blower control. If the blower starts and stops at intervals of 2 or 3 minutes, motor life will be shortened. This also overheats the overload switch in the blower control. Increase by 10° the differential between starting and stopping temperatures on the blower control. This will usually overcome the difficulty.

GAS BURNER MAINTENANCE

Gas burners should be inspected to note the appearance of the gas flame. A yellow flame indicates a poor fuel-air mixture and that carbon is being formed as a result of incomplete combustion. Flame adjustments are made by first adjusting the pressure regulator. The gas pressure is measured by using a U-gage (manometer) as shown in figure 20-30, and the regulator is adjusted to the manufacturer's specifications. To adjust the pressure regulator, remove the cap from the top of the pressure regulator and turn the slotted disk clockwise to increase the pressure and counterclockwise to decrease it. The flame is then adjusted for proper characteristics by using the movable burner dampers. Adjust the air to get a soft blue flame with luminous tips, then increase it slightly until the yellow just disappears.

Frequent cleaning of the unit is necessary if the flame is not adjusted correctly. You should inspect the burner orifices and correct any condition which restricts the flow of gas or changes direction of the gas flow. Also inspect the interior of the combustion chamber and the passages in the heating unit for soot and carbon formations. There should be no formation of soot when the gas is burning completely.

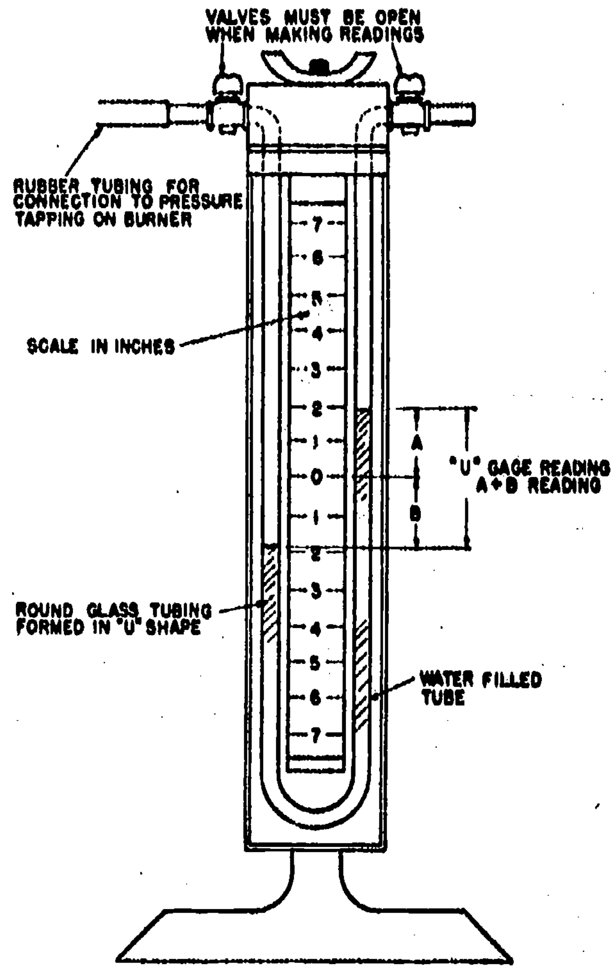

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Figure 20-30.—"U" gage for measuring gas pressure.

MAINTENANCE OF GAS BURNER CONTROLS

Gas burner control systems require very little attention. The maintenance that is required consists of removing and cleaning the pilot, burner, and thermocouple. You should check the system for leaks by using a soapsuds solution, and adjust the dampers if necessary. Also tighten all wiring connections on the control units and clean the electrical contacts of the relays.

TROUBLESHOOTING GAS BURNER SYSTEMS

Either directly or indirectly, the pilot light is the cause of most inoperative gas burners.

Improper positioning of the thermocouple or thermopile and excessive flue and chimney draft conditions account for the greater share of faulty pilot light troubles.

The pilot flame should be of sufficient length to heat the thermocouple and ignite the main burner without delay. It should be a blue color, without a yellow tip. A yellow flame indicates improper combustion, and forms soot on the thermocouple which will insulate it from the heat of the pilot light. The thermocouple must be kept clean and the proper amount of heat must be supplied to it in order to produce a sufficient amount of electricity to operate the thermocouple control relay. Excessive flue draft draws the flame away from the thermocouple. This condition then causes improper heating of the thermocouple, and is corrected by adjusting the dampers. Also a short flame will not heat the thermocouple sufficiently to produce current.

When the thermocouple operates properly, the trouble is most likely in the thermocouple control relay or gas valve. These valves should be checked for poor electrical connections, as well as improper operation of the electrical coils. In some cases, it is necessary to clean the valve seats, plungers, and plunger tubes in the solenoid gas valves. Since these valves are expensive, extreme care should be taken to avoid damage to the internal mechanism.

The limit control, as well as the thermostat, should be checked for proper operation. And proper attention should be given to the condition of all wiring. You should check the manual gas valve for open position. If the fuel supply is suspected, you should use a U-gauge (manometer) to check the gas pressure by connecting it to the pressure tap on the burner and adjusting the pressure to the manufacturer's specifications.

HEATING AND COOLING EQUIPMENT

Heating equipment for air conditioning is usually automatic. Heating coils are usually incorporated in the air-conditioning unit. These coils give up heat from the water or steam which passes through them from a heating unit. Heat

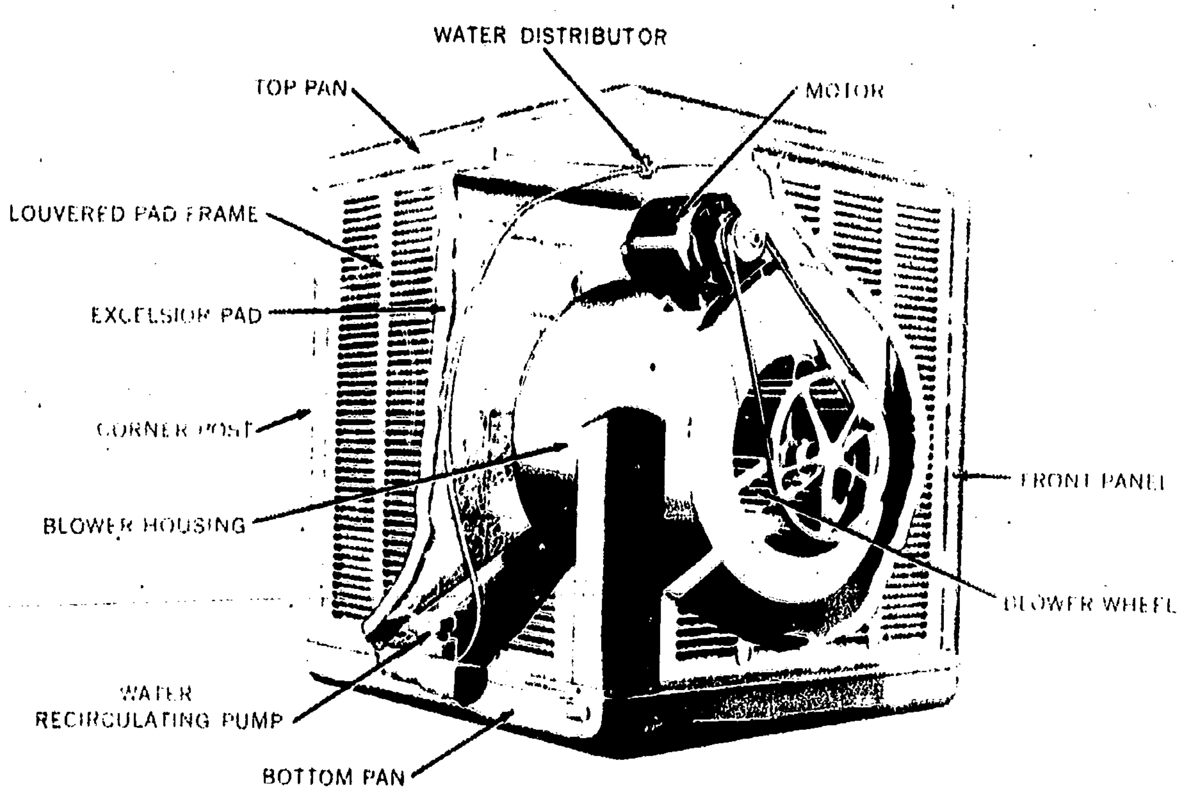

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Figure 20-31.—Cutaway view of drip-type evaporative cooler.

may also be generated within an air-conditioning unit directly by a gas heating unit or by the use of an electrical heater. No matter what type of heat is used, the final goal is to heat the air.

The cooling equipment for air conditioning must be of a type that will satisfactorily cool the air for a particular space that is being air conditioned. One method used to cool air in air-conditioning units is by the evaporation of water. This method of cooling the air is referred to as evaporative cooling. Evaporative cooling of air is accomplished by circulating air through a finely divided water spray or across a wetted surface so that a portion of the water is evaporated continually. Latent heat of evaporation, which must be passed on to water to evaporate it, is supplied from the heat of incoming air, thereby reducing the dry bulb temperature of the air. A cutaway view of the drip-type evaporative cooler is shown in figure 20-31.

One of the most important and positive methods to cool air in air-conditioning units is by mechanical refrigeration. A mechanical refrigeration system for air conditioning is designed with cooling coils which operate in a manner similar to that of an evaporator in a common refrigerator. These coils are usually

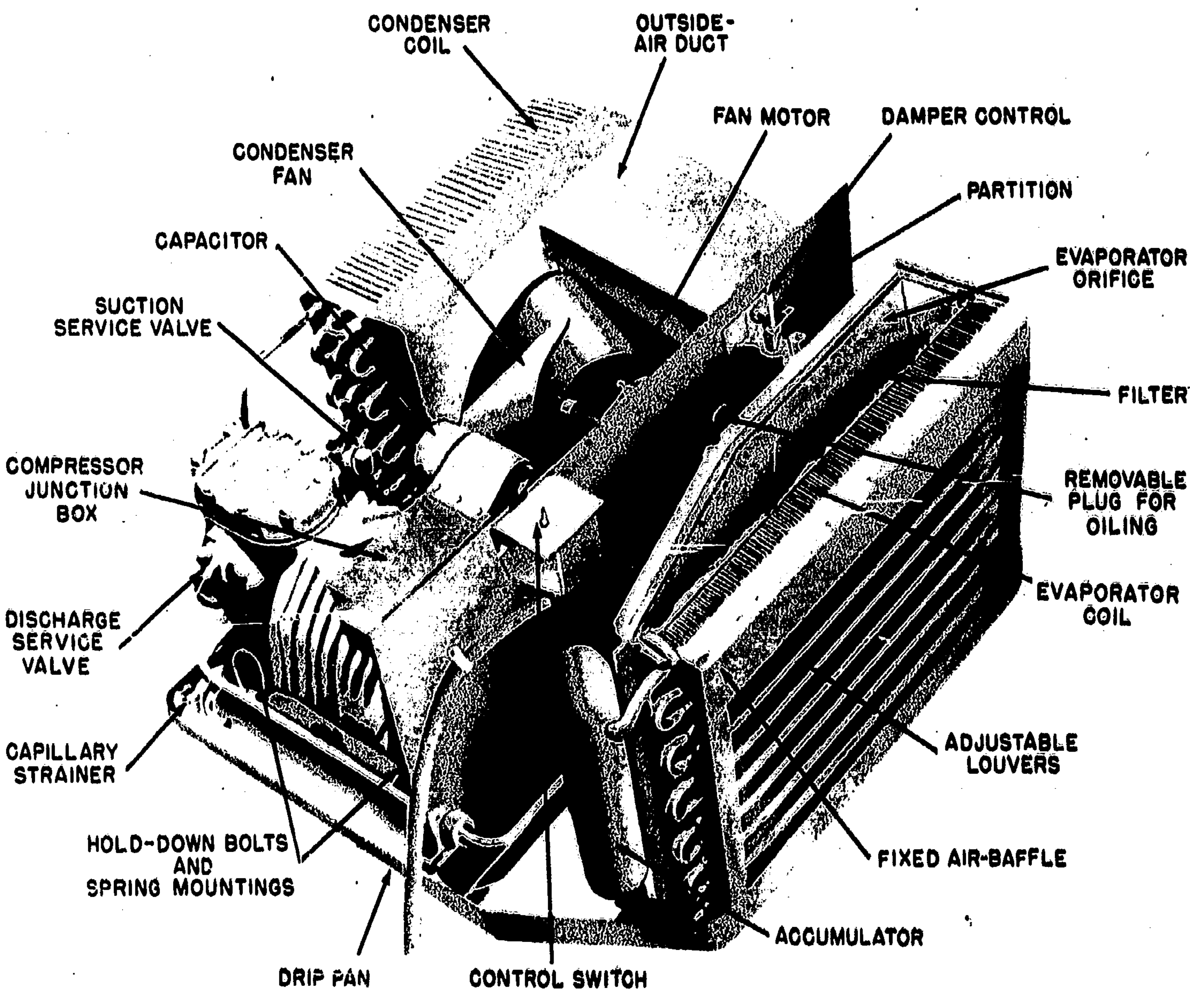

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Figure 20-32.—Window air conditioner.

cooled to about 50° F, and the air to be conditioned and cooled is blown through the coils. Cooling coils of this type also serve as dehumidifiers. If the humidity is high, some of the air that flows through the coils will be cooled below the dew point and will give up some of its moisture causing the air to become dehumidified. This moisture collects on the cooling coils and is carried away by drains or evaporation.

SELF-CONTAINED AIR-CONDITIONING UNITS

Self-contained refrigerative air-conditioning units may be divided into two groups. They are the window- and floor-mounted units.

Window-mounted refrigerative air conditioning units usually range from 4000 to 36,000 Btu's per hour in capacity. (See fig. 20-32.) The utilization of windows for the installation of these units is not a necessity. They may be installed in transoms or directly in outside walls (commonly called a "through-the-wall" installation). The unit must have access to outside air for ventilation and exhaust purposes, and for the air-cooled condenser. A package-type room air conditioner showing air-flow patterns for cooling, ventilating, and exhausting services is illustrated in figure 20-33. It is a good idea to mount the unit on the East side of the building in order to take advantage of the afternoon shade.

In construction and operating principles, the window unit is a small and simplified version of certain parts of a central system. As shown in figure 20-34 and 20-35, the basic refrigeration components are present in the window unit. Cooling of the condenser coils is accomplished by air. Circulation of the room air is accomplished by a fan that blows across the evaporator coils. Moisture that is condensed from the humid air by these coils is collected in a pan at the bottom of the unit; it is usually drained toward the back of the unit, where the condenser fan picks up the drainage in the form of droplets and mist and adds them to the air blast that cools the condenser. Most window units are equipped with thermostats that maintain a fixed dry bulb temperature and moisture content in an area within reasonable limits.

Floor-mounted refrigerative air-conditioning units range in size from 24,000 to 360,000 Btu's per hour and are sometimes referred to as PACKAGE units. These largers units, like window units, contain the complete system of refrigeration components. A self-contained floor unit, with panels removed, is illustrated in figure 20-36. In the average installation of this type of equipment, either water-cooled or air-cooled condensers are used.

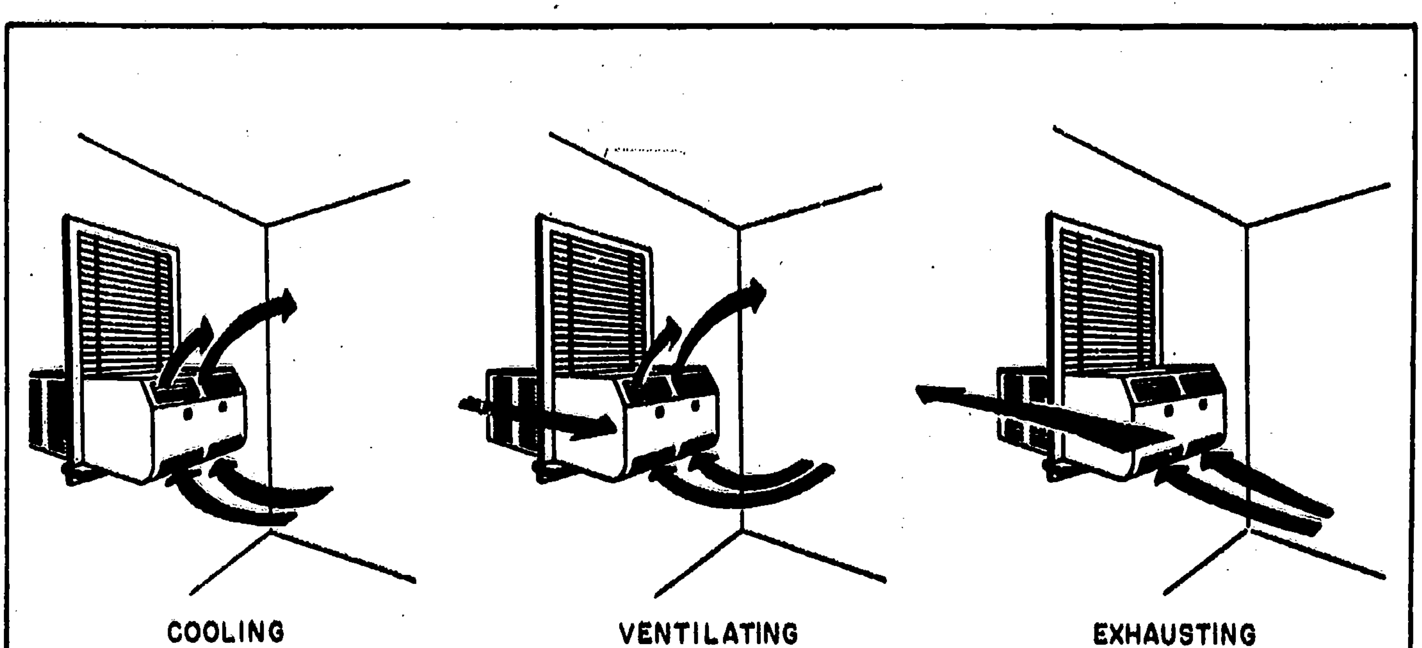

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Figure 20-33. — Package-type room air conditioner showing air-flow patterns for cooling, ventilating, and exhausting services.

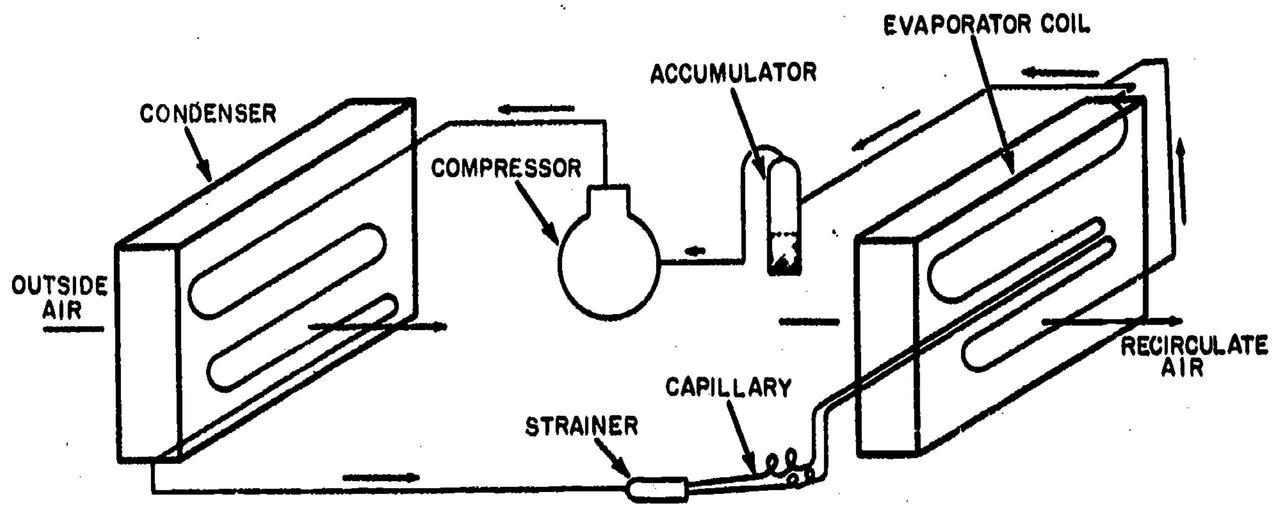

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Figure 20-34.—Refrigerant cycle of a package-type room air conditioner.

OPERATION AND MAINTENANCE

Window-mounted refrigerative air-conditioning units require very little mechanical attention before they are put into operation. The units are either sealed or of the semisealed type (hermetic). Hold-down bolts or wires may have to be removed or loosened prior to starting the unit for the first time.

Self-contained air-conditioning units or systems of all types are operated by users who should be properly instructed in their use.

Window units may be operated by the user as ventilating systems by operating the blower alone. Outside-air-intake dampers of these units are positioned for maximum outside air circulation when used as ventilators. This operation is desirable during cooler seasons of the year when introduction of outside air into the space results in satisfactory room conditions. When ventilation effect is not sufficient, the cooling or compressor control is set to the ON position. When the compressor is operated, outside-air-intake dampers are positioned to admit the minimum amount of outside air for maximum room cooling effect. Direction of supply air flow is regulated by the adjustable

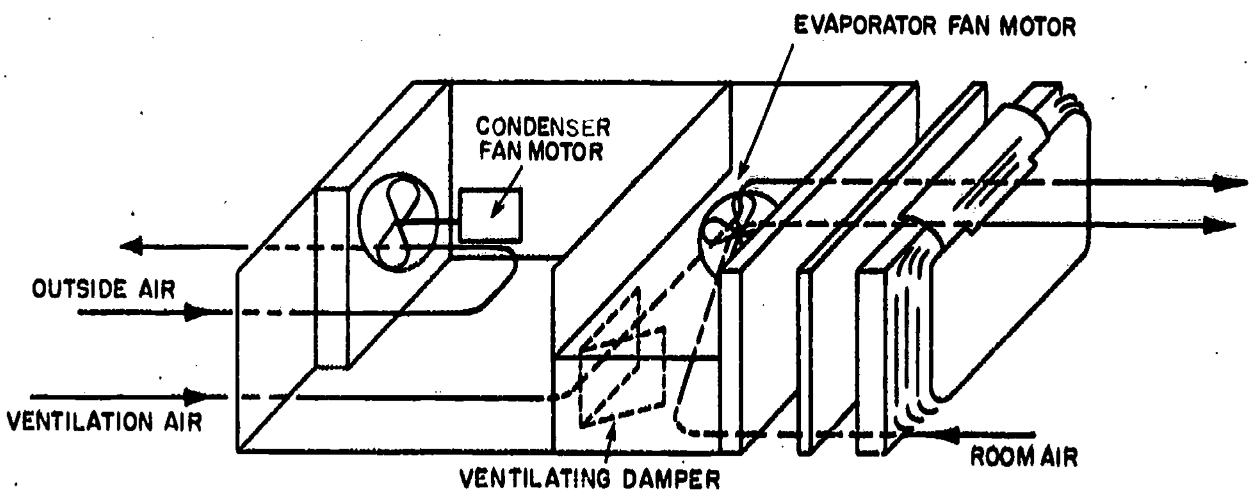

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Figure 20-35.—Air-handling components of a package-type room air conditioner.

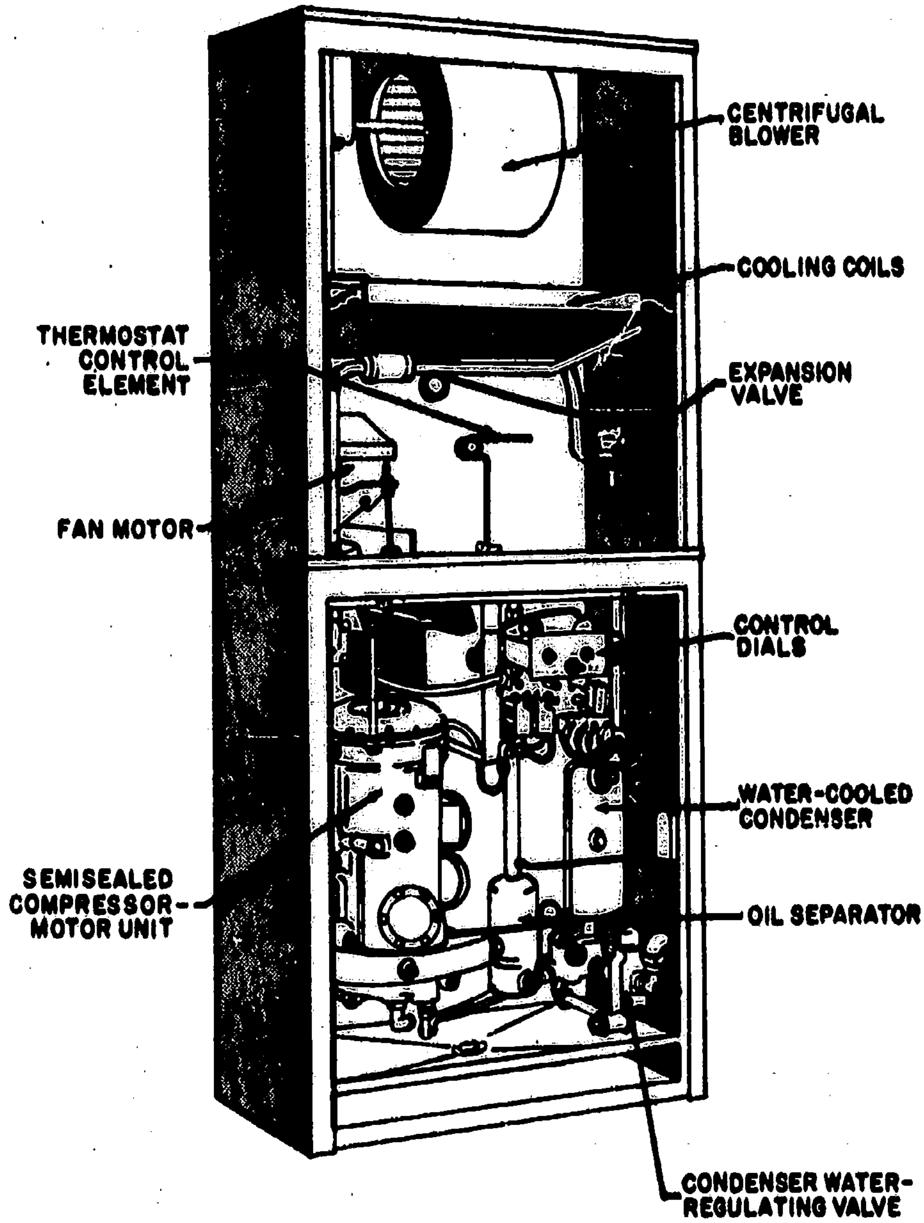

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Figure 20-36. — Floor-mounted air-conditioning unit.

grille on the unit. Starting and stopping of both the blower and compressor motors is usually automatically controlled by the thermostat.

Floor units may also be operated as a ventilating system by operating the blower only. The blower fan is started and stopped by manual operation of the fan switch. When blower operation is not sufficient to provide cooling, the compressor switch is turned to the ON position and the compressor starts and stops by action of the thermostat in accordance with variations in room temperature. Maximum refrigerating cooling effect is produced by systems using recirculated air when the outside air damper is set for introduction of a normal amount of outside air into the system during hot weather. If the system is designed for summer-winter operation, the changeover switch is set at either summer or winter setting as required.

Refrigerating air-conditioning units are operated in the same manner as other refrigerating systems except that they operate at higher temperatures and suction pressures. They should be checked regularly during the season when they are being operated to see that they function in a satisfactory manner. The filters should be renewed or cleaned weekly or more often if necessary. Always stop the blowers when changing the filters in order to keep loose dust from ciculating through the system. Before disturbing the filters in hospitals, especially those serving operating rooms, always determine that no operations are being or are about to be performed. The best time to clean these filters is in the afternoon after surgical work is completed. If the filters are of the permanent type, they should be returned to the shop for cleaning.

At least once each year the unit should be serviced to ensure that it is in suitable condition for the next season's operation. If the unit is designed with a spray humidifier, spray nozzle, water strainers, and cooling coils, each device should be cleaned each month during the season to remove water solids and scale. Cooling coil casings, drain pans, fan scrolls, and fan wheels should be wire-brushed and repainted when necessary. All fan and motor bearings should be checked for excessive wear and replaced if necessary. Oiling and greasing of the blower and motor bearings should be performed as required.

CONTROLS

Controls used in air conditioning are generally the same as for refrigeration systems and include thermostats, humidistats, pressure and flow controllers, and motor overload protectors.

THERMOSTATS

The thermostat is an adjustable temperature-sensitive device which, through the opening and closing of its contacts, controls the operation of the cooling unit. The temperature-sensitive element may be a bimetallic strip, a confined, vaporized liquid, or a temperature- sensitive resistance.

The thermostats used with refrigerative air conditioners are similar to those used with heating equipment, except that their action is reversed. The operating circuit is closed when the room temperature rises to the thermostat control point and remains closed until the cooling unit decreases the temperature sufficiently. In addition, cooling thermostats are not equipped with heat anticipating coils.

Wall type thermostats most commonly used for heating and air conditioning in the home and on some commercial units employ a bimetallic strip and a set of contacts as shown in figure 20-37. This type of thermostat operates on the principle that when two dissimilar metals, such as brass and steel, are bonded together, one tends to expand faster than the other when heat is applied. This will cause the strip to bend and close the contacts.

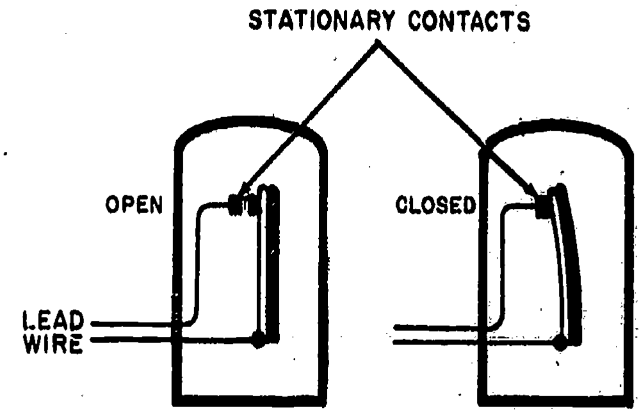

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Figure 20-37.—Bi-metal thermostat.

As a UT you may be required to make a differential adjustment to this type of thermostat. (See figure 20-14.) The differential adjustment sets the temperature difference between the cut-in and cut-out temperatues. For example, if the system were set to cut in at 76° F and cut out at 84° F, then the differential would be 8° F. This is to prevent the unit from cycling continually as it would if there were no differential.

HUMIDISTAT

A room humidistat may be defined as a humidity-sensitive device controlling the equipment which maintains a predetermined humidity of the space where it is installed. The contact of the humidistat is opened and closed by the expansion or contraction of natural blonde hairs from humans, which are one of the major elements of this control. It has been found that these types of hairs are most sensitive to the moisture content of the air surrounding them.

PRESSURE CONTROLLERS

Pressure controllers have already been discussed in chapter 18 of this book. The purpose of these controllers in air conditioning is to act as safety switches for the system, so that if either the head pressure is too high or suction pressure too low the system will be secured regardless of the position of the operating switches.

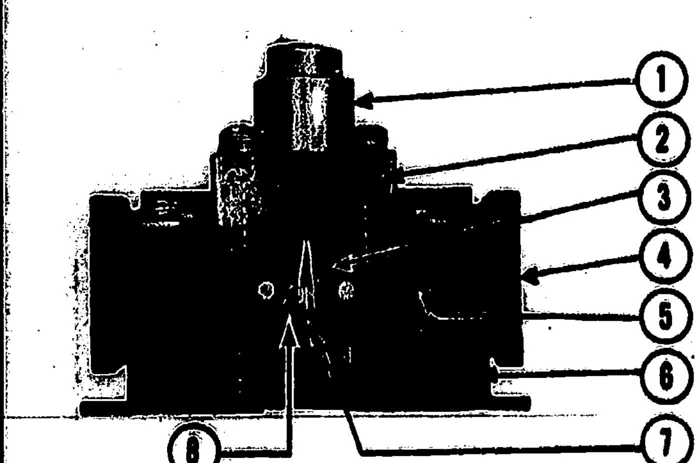
REFRIGERANT-FLOW CONTROLLERS

The refrigerant-flow controllers used with air conditioners are similar to the ones discussed in chapter 18 for refrigeration. These controllers are either of the capillary tube or externally equalized expansion valve type and are usually of larger tonnage than those used for refrigerators.

MOTOR OVERLOADS

When the compressor is powered by an electric motor, either belt-driven or as an integral part of the compressor assembly, the motor is usually protected by a heat-actuated overload device, in addition to the line power fuses. The heat to actuate the overload is supplied by the electrical energy to the motor as well as the heat generated by the motor itself. Either source of heat or a combination of the two, if excessive, will cause the overload to open and remove the motor from the line.

Figure 20-38 shows a thermal-element type of overload cutout relay. It is housed in the magnetic starter box. On current overload, the relay contacts open, allowing the holding coil to release the starting mechanism, thereby stopping the motor.



1. CONTACT STRUCTURE
2. SCREW
3. OPERATING ARM
4. HEATER COIL
5. SOLDER TUBE
6. SCREW
7. SPLITTER ARM

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Figure 20-38. — Thermal overload relay.

TROUBLESHOOTING

Table 20-1 is a troublshooting chart generally applicable to all types of air conditioners. Most manufacturers include more detailed and specific information in publications pertaining to their units. If you find that there is no manual with the unit when it is unpacked, write the manufacturer and request one as soon as possible.

CLEANING WATER-COOLED CONDENSERS

You may be assigned to some activities where water-cooled condensers are used in the air-conditioning system. In such cases, the UT will probably have the job of cleaning the condensers. Information that will assist you in cleaning water-cooled condensers is presented below.

Water contains many impurities, the content of which varies in different localities. Lime and iron are especially injurious; they form a hard scale on the walls of water tubes that reduces the efficiency of the condenser. Condensers can be cleaned mechanically or chemically.

Scale on tube walls of condensers with removable heads is removed by attaching a round steel brush to a rod, and by working it in and out of the tubes. After the tubes have been cleaned with a brush, flush them by running water through them. Some scale deposits are harder to remove than others, and a steel brush may not do the job. Several types of tube cleaners for removing hard scale can usually be purchased from local sources. Be sure that the type selected does not injure water tubes.

The simplest method of removing scale and dirt from condenser tubes not accessible for mechanical cleaning is with an inhibited acid that cleans coils or tubes by chemical action. Figure 20-39 shows the connections and the equipment necessary for cleaning the condenser with an inhibited acid, both when the acid flows by gravity (top view) and when forced circulation is used (bottom view). When scale deposit is not very great, gravity flow of the acid provides sufficient cleaning. When the deposit almost clogs tubes, forced circulation should be used. Prevent chemical solution from splashing in eyes, and on skin or clothing.

Table 20-1.—Troubleshooting Chart for Air Conditioners

Type of unit	Complaint	Cause	Possible remedy
With open-type compressor	Electric motor will not start	Power failure	Check circuit for power source
		Compressor stuck	Locate cause and repair
		Belt too tight	Adjust belt tension
		Manual reset in starter open	Determine cause of overload and repair. Reset overload cutout
		Thermostat setting too high	Lower thermostat setting
		Low voltage	Check with voltmeter, then call power company
		Burned-out motor	Repair or replace
		Frozen compressor caused by locked or damaged mechanism	Remove and repair compressor
	Unit cycles on and off	Intermittent power interruption	Tighten connections or replace defective power supply parts
		High-pressure cutout defective	Replace high-pressure cutout
		High-pressure cutout set too low. Overload opens after having been reset	Raise cutout pressure. Check voltage and current drawn
		Leaky liquid-line solenoid valve	Repair or replace
		Dirty or iced evaporator	Clean or defrost evaporator. Check filters and fan drive
		Overcharge of refrigerant or non-condensible gas	Remove excess refrigerant or purge noncondensible gas
		Lack of refrigerant	Repair refrigerant leak and re-charge
		Restricted liquid-line strainer	Clean strainer
		Faulty motor	Repair or replace faulty motor

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Table 20-1. — Troubleshooting Chart for Air Conditioners — Continued

Type of unit	Complaint	Cause	Possible remedy
With open-type compressor (continued)	Coil frosts	Filters dirty	Clean filters
		Not enough air over coil	Clean or remove restriction from supply or return ducts or grilles
		Defective expansion valve	Replace valve
	Unit runs but will not cool	Unit not fully charged	Recharge slightly, then check for leaks in the refrigerant circuit, then fully charge
		Leaky suction valve or discharge valve	Remove compressor cylinder head and clean or replace valve plate
		Expansion valve not set correctly	Adjust expansion valve
		Strainer clogged	Remove, clean, and replace strainer
		Air in refrigerant circuit. Moisture in expansion-valve orifice	Purge unit of air. Clean orifice and install silica gel dryer
		Flash gas in liquid line	Add refrigerant
	No air blows from supply supply grille	Ice or dirt on evaporator	Clean coil or defrost
		Blower belt broken or loose	Adjust belt tension, or replace belt
		Blower bearing frozen	Repair or replace bearing and lubricate as directed
	Discharge pressure too high	Improper operation of condenser	Correct air flow. Clean coil surface
		Air in system	Purge
		Overcharge of refrigerant	Remove excess or purge
	Discharge pressure too low	Lack of refrigerant	Repair leak and charge

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Table 20-1.—Troubleshooting Chart for Air Conditioners—Continued

Type of unit	Complaint	Cause	Possible remedy
With open-type compressor (continued)	Discharge pressure too low (continued)	Broken or leaky compressor discharge valves	Remove head, examine valves and replace those found to be operating improperly
	Suction pressure too high	Overfeeding of expansion valve	Regulate superheat setting expansion valve and check to see that remote bulb is properly attached to suction line
		Expansion valve stuck in open position	Repair or replace valve
		Broken suction valves in compressor	Remove head, examine valves and replace those found to be inoperative
	Suction pressure too low	Lack of refrigerant	Repair leak and charge
		Clogged liquid line strainer	Clean strainer
		Expansion valve power assembly has lost charge	Replace expansion-valve power assembly
		Obstructed expansion valve	Clean valve and replace if necessary
		Contacts on control thermostat stuck on closed position	Repair thermostat or replace if necessary
With hermetic motor-compressor combination	Compressor runs continuously; good refrigeration effect	Air over condenser restricted	Remove restriction or provide for more air circulation over the condenser
	Compressor runs continuously; unit is too cold	Thermostatic switch contacts badly burned	Replace thermostatic switch
		Thermostatic switch bulb has become loose	Secure bulb in place
		Thermostatic switch improperly adjusted	Readjust thermostatic switch

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Table 20-1. — Troubleshooting Chart for Air Conditioners — Continued

Type of unit	Complaint	Cause	Possible remedy
With hermetic motor-compressor combination (continued)	Compressor runs continuously; little refrigeration effect	Extremely dirty condenser	Clean condenser
		No air circulating over condenser	Provide air circulation
		Ambient temperature too high.	Provide ventilation or move to a cooler location
		Load too great	Analyze load
	Compressor runs continuously; no refrigeration	A restriction that prevents the refrigerant from entering the evaporator. A restriction is usually indicated by a slight refrigeration effect at the point of restriction	Locate the possible points of restriction, and try jarring with a plastic hammer, or heating to a temperature of about 110 degrees F. If the restriction does not open, replace the unit
		Compressor not pumping. This would be indicated by a cool discharge line and a hot compressor housing. The wattage is generally low	Replace the unit
		Short of refrigerant	See manufacturer's instructions
	Compressor short cycles, poor refrigeration effect	Loose electrical connections	Locate loose connections and make them secure
		Defective thermostatic switch	Replace thermostatic switch
		Defective motor starter	Replace defective motor starter or relay
		Air restriction at evaporator	Remove air restriction
	Compressor short cycles, no refrigeration	Dirty condenser	Clean the condenser
		Ambient temperature too high	Provide ventilation or move to a cooler location
		Defective wiring	Repair or replace defective wiring

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Table 20-1.—Troubleshooting Chart for Air Conditioners—Continued

Type of unit	Complaint	Cause	Possible remedy
With hermetic motor-compressor combination (continued)	Compressor short cycles, no refrigeration (continued)	Thermostatic switch operating erratically	Replace thermostatic switch
		Relay erratic	Replace relay
	Compressor runs too frequently	Poor air circulation around the condenser or too high ambient temperature	Increase the air circulation around the condenser. In some localities the temperature is extremely high, and nothing can be done to correct this
		Load too great. Worn compressor. Generally accompanied by rattles or knocks	Analyze end use. Replace unit or bring it to the shop for repairs
	Compressor does not run	Motor is not operating	If the trouble is outside the sealed unit, it should be corrected; for example, wires should be repaired or replaced and thermostatic switches or relays should be replaced. If the trouble is inside the sealed unit, the sealed unit should be replaced
	Compressor will not run (Assume that the thermostatic switch and relay, and the electric wiring and current supply are in good condition and operating normally)	If the cabinet has been moved, some oil may be on top of the piston	Wait an hour or so, and then attempt to start the motor by turning the current on and off many times. On some compressors, it may be necessary to wait 6 or 8 hours.
		Compressor may be stuck, or some parts may be broken	Replace the unit
		Connections may be broken on the inside of the unit, or the motor winding may be open	Replace the unit. Sometimes after sealed units have been standing idle for a long time the piston may stick in the cylinder wall. It is sometimes possible to start the compressor by turning on the current and bumping the outer housing with a rubber mallet.

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Table 20-1. — Troubleshooting Chart for Air Conditioners — Continued

Type of unit	Complaint	Cause	Possible remedy
With hermetic motor-compressor combination (continued)	Compressor is unusually hot.	Condenser is dirty, or there is a lack of air circulation	Clean the condenser; increase the air circulation
		Unusually heavy service or load	If possible, decrease load. Perhaps another unit is required
		Low voltage	This could be caused by too small feed wires. If the wires feeding the refrigerating unit become warm, it is an indication that they are too small and should be replaced with larger wires
		A shortage of oil	Add oil if possible; if this is not possible, the unit must be replaced. A shortage of refrigerant will cause a shortage of oil in the crankcase of the compressor
	No refrigeration after starting up after a long shutdown or on delivery	Generally, during a long shutdown, an amount of liquid refrigerant will get into the crankcase of the compressor. When this happens, the compressor operation will cause no noticeable refrigeration effect until all the liquid refrigerant has evaporated from the crankcase	Allow the compressor to operate until its internal heat drives the liquid refrigerant from the crankcase. Under some conditions, this may take as long as 24 hours. This time can be shortened by turning an electric heater on the compressor and raising the compressor temperature, not exceeding 110 degrees F.
	Compressor is noisy	Mountings have become worn or deteriorated. The walls against which the unit is placed may be of an extremely hard surface and may resound and amplify the slight noise from the compressor into the room	Replace the rubber mountings. Place a piece of sound-absorbing material on the wall against which the unit is placed, or move the unit to a new location
		Shortage of oil and/or refrigerant	Add oil and refrigerant if possible. If it is impossible, the unit must be replaced
		The sealed unit mechanism has become worn	Replace the unit

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Table 20-1.—Troubleshooting Chart for Air Conditioners—Continued

Type of unit	Complaint	Cause	Possible remedy
With hermetic motor-compressor combination (continued)	After each defrosting there is a long on cycle before refrigeration is again normal	Slight shortage of refrigerant	Add refrigerant if possible; if not, replace the unit
		Condenser is dirty	Clean the condenser
		Thermostatic switch bulb is loose	Secure the bulb in place
		There is a restriction between the receiver or condenser and/or the evaporator	Attempt to remove the restriction by jarring with a plastic hammer or by heating the possible points of restriction to about 110 degrees F. If this does not correct the trouble, the unit must be replaced or brought to the shop for repairs

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Equipment and connections for circulating inhibited acid through the condenser using gravity flow, as illustrated in figure 20-34, are:

1. A crock or wooden bucket for mixing solution. Do not use galvanized materials because prolonged contact with acid deteriorates such surfaces.
2. Another crock or wooden bucket for catching the drainage residue.
3. One-inch steel pipe of sufficient length to make connections shown.
4. Fittings for 1-inch steel pipe. The vent pipe shown should be installed at the higher connection of the condenser.

Equipment and connections for circulating inhibited acid through the condenser using forced circulation, as illustrated in figure 20-39, are:

1. A pump suitable to this application. A centrifugal pump and a 1/2-horsepower motor is recommended (30 gallons per minute at 35-ft head capacity).
2. A nongalvanized metal tank, stone, or porcelain crock, or wooden barrel with capacity of approximately 50 gallons, with ordinary bronze or copper screening to keep large pieces of scale or dirt from getting into the pump intakes.
3. One-inch steel pipe of sufficient length to make piping connections shown.
4. Fittings for 1-inch steel globe valves. The vent pipe, as shown, should be installed at the higher connection of the condenser.

Handle the inhibited acid used for cleaning condensers with the usual precautions observed when handling acids. It stains hands and clothing and attacks concrete. If the inhibitor is not present, it attacks steel. Therefore, use every precaution to prevent spilling or splashing. Where splashing might occur, cover surfaces with burlap or boards. Gas produced during cleaning, that escapes through the vent pipe, is not harmful, but care should be taken to prevent any liquid or spray from being carried through with the gas. The basic formula should be maintained as closely as possible but a variation of 5 percent is permissible. The inhibited acid solution is made up of the following:

1. Water.

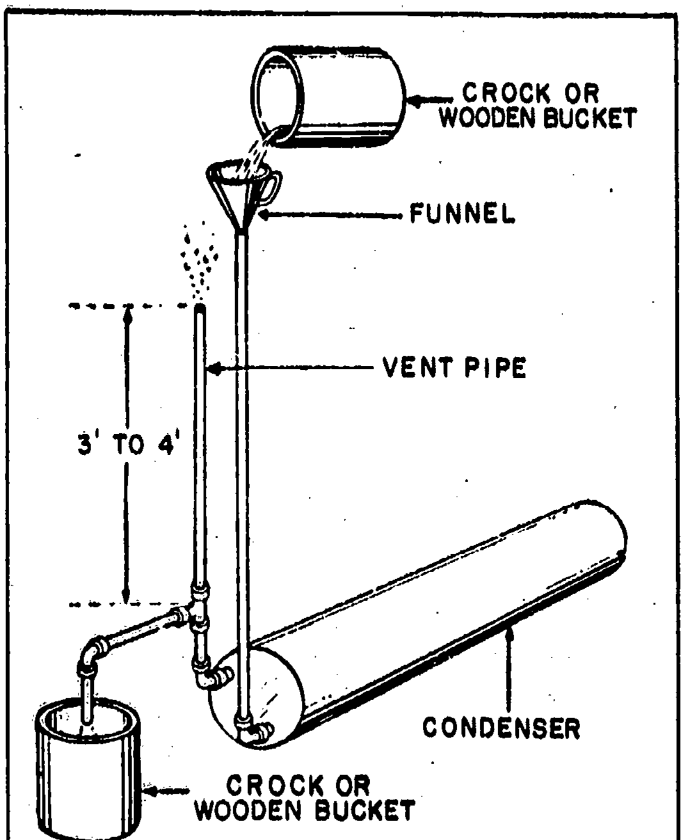

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Figure 20-39.—Cleaning water-cooled condensers with acid solution.

2. Commercial hydrochloric (muriatic) acid, with specific gravity of 1.19. Eleven quarts of acid should be used for each 10 gallons of water.

3. Three and two-fifths ounces of inhibitor powder for each 10 gallons of water used.

4. Place the required amount of water in a nongalvanized metal tank or wooden barrel and add the necessary amount of inhibitor powder while stirring the water. Continue stirring the water until the powder is completely dissolved, then add the required quantity of acid. NEVER add water to acid; this may cause an explosion.

In charging the system with acid solution, when GRAVITY FLOW is used, introduce the inhibited acid as shown in figure 20-39. Do not add solution faster than the vent can exhaust the gases that are generated during cleaning. When the condenser has been filled, allow the solution to remain here overnight.

When FORCED CIRCULATION is used, the valve in the vent pipe should be fully opened while solution is introduced into the condenser, but must be closed when the condenser is completely charged and the solution is circulated by the pump. When a centrifugal pump is used, the valve in the supply line may be fully closed while the pump is running.

The solution should be allowed to stand or be circulated in the system overnight for cleaning out average scale deposits. The cleaning time will also depend on the size of the condenser to be cleaned. For extremely heavy deposits, forced circulation is recommended, and the time should be increased to 24 hours. The solution acts more rapidly if it is warm, but the cleaning action is just as thorough with a cold solution if adequate time is allowed.

After the solution has been allowed to stand or has been circulated through the condenser the required length of time, it should be drained out and the condenser thoroughly flushed with water. To clean condensers with removable heads by using inhibited acid, the above procedure can be used without removing the heads; however, extra precaution must be exercised in flushing out condensers with clear water after acid has been circulated through the condenser to ensure acid removal from all water passages.

SAFETY MEASURES

Toxic or flammable refrigerants are never used in comfort air-conditioning systems. Anhydrous ammonia is toxic and flammable, and methyl chloride refrigerant is moderately so; therefore, neither of these should be used for comfort air conditioning. Most modern units use R-12 or R-22 refrigerants, which are not toxic except when decomposed by a flame. If the liquefied refrigerant comes in contact with the eyes, the person suffering the injury must be taken at once to a doctor.

As first aid treatment, avoid rubbing or irritating the eyes, and put drops of sterile mineral oil into them as an irrigative agent. The eyes must then be washed, if irritation continues, with a weak boric acid solution or a sterile salt solution not to exceed 2 percent of ordinary table salt. Should the skin come in contact with the liquefied refrigerant, the skin is to be treated as though it had been frostbitten or frozen. Frostbite is a term applied to the effect of extreme cold on any part of the body. Severe freezing of the deeper tissues is dangerous and often results in gangrene. A frostbitten area is unnaturally white and feels numb. The area is treated to restore the circulation and normal warmth of the affected part. The treatment must not be too vigorous. Rubbing the frostbite with snow or ice was a method long in use but is now considered dangerous because it is likely to remove the skin and damage local tissues. Rapid thawing in warm water has become the accepted treatment for frostbite. Time is crucial and the sooner the tissues are warmed, the better the results. Irreparable damage may occur when the extremities are frozen for several hours. The quick thaw is accomplished by placing the frostbitten parts in water of approximately 110° F. This is as warm as many people can stand. The thawing skin becomes red and warm; it burns, aches, or throbs. But once the part has thawed, there is no need to warm it any further. Dry the skin and lie flat in bed with the extremities exposed to the warm air of the room or cover them with flannel or cotton, and protect them from injury. Treat the damaged tissues gently and avoid walking if possible. Consult a physician, because additional measures may be essential to avoid gangrene.

Do not adjust, clean, lubricate, or service any parts that are in motion. Ensure that moving parts such as pulleys, belts, or flywheels are fully enclosed with proper guards.

Before making repairs, open all electric switches controlling the equipment. Tag and lock the switches to prevent short circuits or accidental starting of equipment. When moisture and brines are on the floor, fatal grounding through the body is possible when exposed electrical connections can be reached or touched by personnel. Deenergize electrical lines before repairing them, and ground all electrical tools.

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