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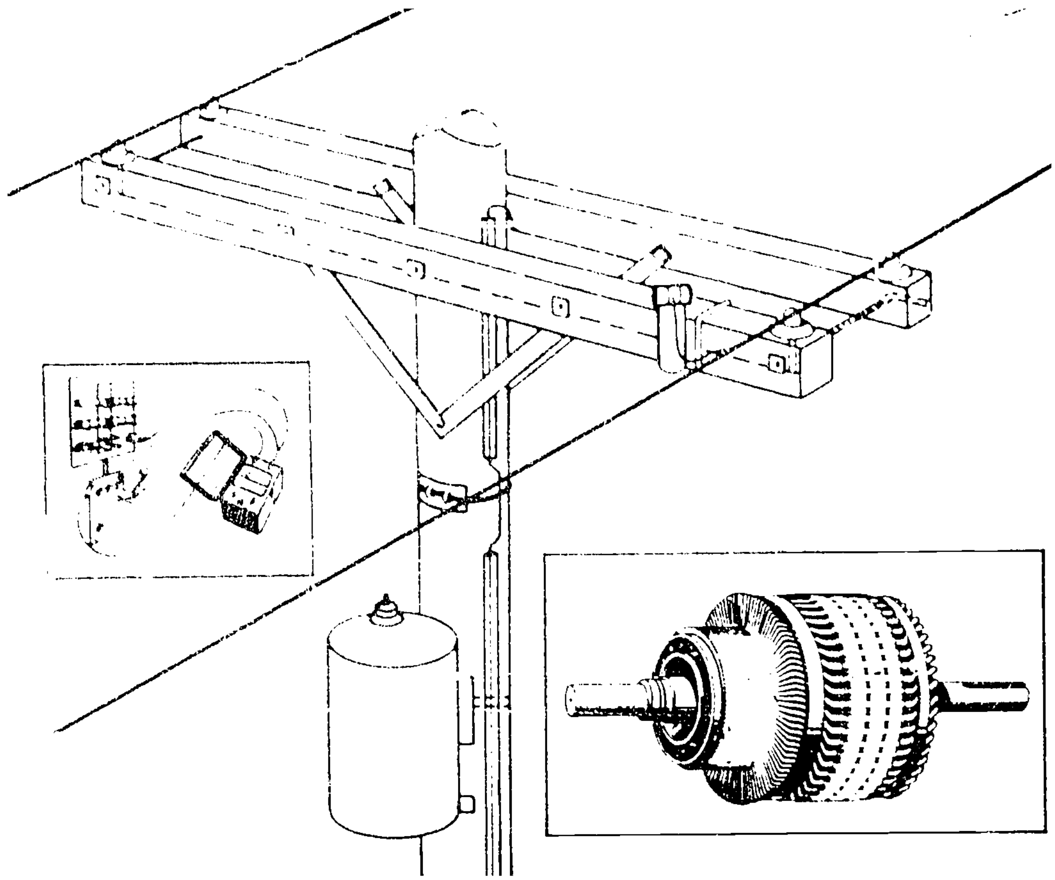
ABSTRACT

One of a series of training manuals prepared for enlisted personnel in the Navy and Naval Reserve, this self-study package provides subject matter that relates directly to the tasks required of the Construction Electrician, which include abilities to install, operate, service, and overhaul electric generating and distribution systems and wire communications systems; and control the activities of individuals and crews who string, install, and repair interior, overhead, and underground wires and cables, and attach and service units, such as transformers, switchboards, motors, and controllers. Contents include a 15-chapter text followed by a subject index and the associated nonresident career course (12 reading assignments and technical questions based upon each occupational standard in the respective assignment.) Chapter headings are (1) Meet the Construction Electrician, (2) Safety, (3) Blueprints, Diagrams, and Schematics, (4) Special Tools, (5) Test Equipment, (6) Control and Protective Equipment, (7) Shopwork, (8) Interior Wiring, (9) Central Power Stations, (10) Overhead Power Distribution, (12) Communications Systems, (13) Telephone Cable Splicing, (14) Administration, and (15) Basic Electronic Components and Circuits. The appendix includes the U.S. customary and metric system units of measurement. (HD)



PREFACE

The ultimate purpose of training naval personnel is to produce a combatant Navy which can ensure victory at sea. A consequence of the quality of training given them is their superior state of readiness. Its result is a victorious Navy.

This Rate Training Manual and Nonresident Career Course (RTM/NRCC) form a self-study package that will enable ambitious Construction Electricians to help themselves fulfill the rating. Among these requirements are the abilities to install, operate, service, and overhaul electric generating and distribution system and wire communications system; and control the activities of individuals and crews who string, install, and repair interior, overhead, and underground wires and cables, and attach and service units, such as transformers, switchboards, motors, and controllers.

Designed for individual study and not formal classroom instruction, the RTM provides subject matter that relates directly to the tasks required of the Construction Electrician. The NRCC provides the usual way of satisfying the requirements for completing the RTM.

The set of assignments in the NRCC includes learning objectives and supporting items designed to lead students through the RTM.

This RTM/NRCC was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida for the Chief of Naval Education and Training. Technical assistance was provided by the Civil Engineer Support Office, NCBC Port Hueneme, California, the Naval Construction Training Center, Port Hueneme, California; and the Naval Construction Training Center, 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 CONSTRUCTION ELECTRICIAN

:onstruction Electricians plan, supervise, and orm tasks required to install, operate, serv- and overhaul electric generating and dis- ution systems and wire communications ems; control activities of individuals and /s who install and repair interior, over- l, and underground wires and cables; attach service units, such as transformers, switch- 'ds, motors , and controllers; and schedule evaluate installation and operational routines.

\s a CE you will probably be performing · assigned tasks while serving in a Naval ile Construction Battalion that is engaged verseas construction. There you can expect oe in "B" company, which operates as a cial construction company for battalion pro- s or as a rifle company in a combat situation. re is also a chance you could be assigned in Amphibious Construction Battalion, either one at Little Creek, Virginia or Coronado, ifornia. Some CE's are assigned to Con- iction Battalion Maintenance Units. Their :s concern maintenance of advanced bases. er billets to which CE's are assigned include CE school at Port Hueneme, California instructor duty), Naval Education and Train- Program Development Center at Pensacola, rida (for development of training publications advancement examinations), and Public Works artments at naval shore activities.

THE PUBLIC WORKS DEPARTMENT

When you are assigned to duty at a shore ivity, either within the United States or over- .s, you will most likely be assigned to the olic Works Department of the station. Most tions which have more than about 100 men l 15 or 20 buildings have a Public Works oartment (which administers and maintains olic works and utilities), except that in some alities Public Works Centers have been established. A Public Works Center performs the public works duties for a number of Navy activities in that vicinity.

The Public Works Department is headed by a Public Works Officer, who is an officer of the Civil Engineer Corps. The organization and staffing of the Department varies considerably, depending on the size, location, and mission of the activity. The larger Public Works Departments are generally divided into Administrative and Technical Divisions (Administrative, Engineering, Maintenance Control, and sometimes Housing) and Operating Divisions (Maintenance, Utilities, and Transportation). The Operating Divisions are usually headed by a CEC officer who has the title Shops Engineer. Smaller stations might have only three divisions: Administrative, Engineering, and Shops. The Shops Division usually has a Transportation Branch.

Some Public Works Departments, particularly at small, isolated stations, may be staffed entirely by military personnel, but most Public Works Departments, both in the United States and overseas, are staffed largely by civilians. The Administrative and Technical Divisions (except for Maintenance Control) are mainly staffed with civil servants classed as GS, or per annum, or white collar employees. The Operating Divisions are mainly staffed with civil servants classed as wage board, or per diem, or blue collar employees. Supervisory blue collar employees have titles such as (in ascending order of responsibility) snapper, head, leadingman, quarterman, and chief quarterman. Very large stations may also have master mechanics and foreman mechanics. At bases overseas, foreign nationals may be hired to work in the Public Works Department. They may be employed directly as a special category of civil servant, or they may be utilized as contract labor through the negotiation of a labor contract with the host government of the country involved.

DUTY WITHIN THE U.S.

As stated before, if you are assigned to shore activity within the U.S. you will most likely be assigned to Public Works; but this is not always the case. In areas where there is a large stable supply of manpower, most of the utilities work is done by blue collar employees. Therefore, you may be assigned to the master at arms force, special services, the salvage yard, the commissary, or to any of a great variety of jobs.

Your chances of working at your trade are much better in areas where there is a relative shortage of manpower. In these areas, you may expect to be assigned to the Utilities Division or the Maintenance and Utilities Branch of the Shops Division of a Public Works Department. Some Public Works Officers prefer to organize two separate lines of authority: one for civilians and one for the military personnel. Others prefer to integrate the civilians and military completely; in the latter case you may work beside a civilian and report to a CE1, who reports to a quarterman, who answers to the Shops Engineer, who is an officer. There are some activities which are staffed completely by military personnel because the mission is highly classified; if you are assigned to a station of this type you may expect to work within your rating.

DUTY AT OVERSEAS BASES

In general, you may expect to work in your trade if assigned to a shore activity outside the U.S. At smaller, relatively isolated stations the entire Public Works staff may be military personnel. At the larger activities you may expect to work with civil servants from the U.S., both white collar and blue collar, and with foreign nationals.

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 Construction Electrician (CE) rating, which is a straight progression from Construction Recruit (CR) to Master Chief Utilitiesman (UTCM).

Construction Electrician

CR-CA-CN-CE3-CE2-CE1-CEC-CECS-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.

OCCUPATIONAL STANDARDS

A most important step in developing your career is to acquire the skills that have been prescribed specifically for each paygrade of the CE rating. These skills, expressed in terms of task statements called occupational standards, are contained in the Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, NAVPERS 18068-D. Other requirements, called naval standards, are not specifically rating oriented. These too are contained in NAVPERS 18068-D. Studying this rate training manual should help you meet the occupational standards for CE3 or CE2. Naval standards can be met by studying other training manuals which are named later in this chapter.

NAVY ENLISTED CLASSIFICATIONS

Associated with the Construction Electrician rating are Navy Enlisted Classifications (NEC's) which identify skills requiring more specific identification than is provided by rates and ratings, and which are not rating-wide requirements. NEC's are designed to facilitate management of manpower by identifying accurately billets and personnel. They help in distribution and detailing of personnel. The following NEC's may be earned by Construction Electricians:

1. SHORE-BASED POWERPLANT TECHNICIAN, CE-5632—He operates, services, and performs organizational and/or intermediate level maintenance on electrical systems of shore-based powerplants. This NEC is assigned only to personnel in pay grades E-5 through E-7 upon satisfactory completion of the applicable course.

2. CENTRAL OFFICE EXCHANGE TECHNICIAN, CE-5642—He installs, inspects, maintains, and performs organizational and/or intermediate level maintenance on automatic PBX or PAX telephone exchange equipment, including switchboards, dial selection mechanisms, and telephones; performs troubleshooting operations; performs necessary adjustments and replacements; cleans and adjusts contacts and adjusts contact clearances; tests circuits using spring tension gages, voltmeters, and ohmmeters; performs daily or periodic ground or insulation tests on switchboards. This NEC is assigned only to personnel E-5 through E-7 upon satisfactory completion of the applicable course.

3. CABLE SPLICING TECHNICIAN, CE-5644—He splices multiple conductor cables used in telephone and telegraph communications and electric-power transmission systems. This NEC is assigned only to personnel E-5 through E-7 upon satisfactory completion of the applicable course.

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. This NEC is assigned not only to CE's, but also to EA's, BU's, UT's, and SW's in pay grades E-5 through E-7, who are graduates of the course, Engineering Aids/Planning and Estimating.

5. ADVANCED UNDERWATER CONSTRUCTION TECHNICIAN, BU-5931—He performs underwater construction operations using all types of underwater equipment and tools. In doing this, he 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 failures. This NEC is available to SEABEE personnel in paygrades E-5 through E-9.

6. BASIC UNDERWATER CONSTRUCTION TECHNICIAN, BU-5932—He performs underwater construction operations using common underwater tools, equipment, and materials. In doing this, he performs duties related to underwater construction blasting; component emplacement and assembly; underwater cutting and welding; seafloor surveying; foundations and anchor emplacement; rigging; cable laying and splicing; and system testing. This NEC is available to SEABEE personnel who are graduates of the Basic Underwater Construction Technician course.

7. SAFETY INSPECTOR, SW-6021—He organizes and supervises the operation of the safety department. In doing this, he investigates accidents, analyzes accidents and problem areas, and recommend methods to decrease frequency and/or eliminate accidents; collects data to ascertain accident trends; inspects project sites, grounds, buildings and machinery to isolate hazards to life, health, and equipment; conducts safety education campaigns by preparing and/or distributing literature, posters, charts, and displays; organizes and directs the safety committee; directs placement of traffic control signs and devices. This NEC is assigned to SEABEE personnel in paygrades E-6 and E-7 who satisfactorily complete two courses: Basics of Occupational Safety and Health (OSH-300) and Occupational Safety and Health Standards of the Construction Industry (OSH-220).

8. NUCLEAR POWERPLANT OPERATOR, 3391—He operates, maintains, and performs organizational level maintenance on nonpropulsive nuclear powerplants and radioisotope power devices, as an Electrical, Mechanical, Instrument or Health Physics/Plant Chemistry Specialist. This NEC is normally assigned to CE's in pay grades E-4 through E-7 who are graduates of the course, Nuclear Powerplant Operators, which is offered at the Naval Nuclear Power Unit at Fort Belvoir, Virginia. NEC 3391 is also available to personnel in the UT, EO, CM, SW, and HM ratings.

THE NAVY ENLISTED ADVANCEMENT SYSTEM

Many of the rewards of Navy life are earned through the advancement system. The basic ideas behind the system have remained stable for many years but specific portions may change rather rapidly. It is important that you know the system and follow changes carefully. BUPERS Notice 1418 will normally keep you up to date.

The normal system of advancement may be easier to understand if it is broken into two parts:

1. Those requirements that must be met before you may be considered for advancement.

2. Those factors that actually determine whether or not you will be advanced.

QUALIFYING FOR ADVANCEMENT

In general, to QUALIFY (be considered) for advancement, you must first:

1. Have a certain amount of time in pay grade.

2. Demonstrate knowledge of material in your mandatory Rate Training Manuals by achieving a suitable score on your Command's test, by successfully completing the appropriate Nonresident Career Courses (NRCC's) or, in some cases, by successfully completing an appropriate Navy School.

3. Demonstrate the ability to perform all the skill requirements listed on the Record of Practical Factors, NAVEDTRA 1414/1.

4. Be recommended by your commanding officer.

5. For petty officer third and second candidates ONLY, demonstrate knowledge of military subjects by passing a locally administered MILITARY/LEADERSHIP examination based on the naval standards (from NAVPERS 18068-D).

6. Demonstrate knowledge of the skill requirements for your rate by passing a Navywide advancement examination based on the occupational standards (from NAVPERS 18068-D).

Figure 1-1 gives a detailed view of the requirements for advancement of active duty personnel; figure 1-2 gives this view for advancement of inactive duty personnel. Remember that the naval and occupational standards can change. Check with your division officer or training officer to be sure that you have the most recent standards.

If you meet all of the above requirements satisfactorily, you become a member of the group from which advancements will be made.

WHO WILL BE ADVANCED?

Advancement is not automatic. Meeting all of the requirements makes you eligible but does not guarantee your advancement. Some of the factors that determine which persons, out of all of those QUALIFIED, will actually be advanced in rate are: the score made on the advancement examination, the length of time in service, the performance marks earned, and the number of vacancies being filled in a given rate.

If the number of vacancies in a given rate exceeds the number of qualified personnel, then ALL of those qualified will be advanced. More often, the number of qualified people exceeds the vacancies. When this happens, the Navy has devised a procedure for advancing those who are BEST qualified. This procedure is based on combining three personnel evaluation systems:

Merit rating system (Annual evaluation and C.O. recommendation).

Personnel testing system (Advancement examination score—with some credit for passing previous advancement exams).

Longevity (seniority) system (Time in Rate and Time in Service).

Simply, credit is given an individual in three areas: performance, knowledge, and seniority. A composite known as the final multiple score is generated from these three factors. All of the qualified candidates from a given advancement examination population are then placed on one list, based on this composite figure, the highest achiever first, and so on down to the last qualified person in the population. For candidates for E-4, E-5, and E-6, advancement authorizations are then issued, beginning at the top of the list, for the number of persons needed to fill the existing vacancies. Candidates for E-7 whose final multiple scores are high enough will be designated PASS SELBD ELIG (Pass Selection Board Eligible). This means that their names will be placed before the Chief Petty Officer Selection Board, a BUPERS board charged with considering all so-designated eligible candidates for advancement to CPO. Advancement authorizations for those being advanced to CPO are issued by this board.

Who, then, are the individuals who are advanced? Basically, they are the ones who achieved the most in preparing for advancement. They were not content to just qualify; they went the extra mile in their training, and through that training and their work experience they

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 comple- tion of Recruit Training.	8 mos. as E-2.	6 mos. as E-3. 2 years time in service.	12 mos. as E-4. 3 years time in service.	24 mos. as E-5. 6 years time in service.	36 mos. as E-6. 9 years time in service.	36 mos. as E-7. 8 of 12 years time in service must be enlisted.	36 mos. as E-8. 10 of 15 years time in service must be enlisted.
SCHOOL	Recruit Training. (C.O. may ad- vance up to 10% of gradu- ating class.)		Class A for PR3, DT3, IS3, AME3, HM3, PN3, FTB3, MT3.			Navy School for AGC, MUC, MNC. ††		
PRACTICAL FACTORS	Locally prepared check- offs.	Record of Practical Factors, NAVEDTRA 1414/1, must be completed for E-3 and all PO advancements.						
PERFORMANCE TEST			Specified ratings must complete applicable performance tests be- fore taking examinations.					
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in ad- vancement multiple.					
EXAMINATIONS**	Locally prepared tests.	See below.	Navywide examinations required for all PO advancements.			Navywide selection board.		
RATE TRAINING MANUAL (INCLUD- ING MILITARY REQUIREMENTS)		Required for E-3 and all PO advancements unless waived because of school comple- tion, but need not be repeated if identi- cal course has already been completed. See NAVEDTRA 10052 (current edition).					Nonresident career courses and recommended reading. See NAVEDTRA 10052 (current edition).	
AUTHORIZATION	Commanding Officer		NAVEDTRAPRODEVCEN					

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

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 9 yrs service	36 mos. with total 12 yrs service	24 mos. with total 15 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, NavEdTra 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		NAVEDTRA PRODEVCEN					

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

Figure 1-2. –Inactive duty advancement requirements.

developed greater skills, learned more, and accepted more responsibility.

While it cannot guarantee that any one person will be advanced, the advancement system does guarantee that all persons within a particular rate will compete equally for the vacancies that exist.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement? You must study the naval and occupational standards, demonstrate that you can perform required skills, study the required rate training manuals, and study other material that is required for advancement. To prepare for advancement, you will need to be familiar with (1) the Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, (2) the Record of Practical Factors, (3) the Bibliography for Advancement Study, and (4) the applicable rate training manuals. The following sections describe each of these and give you some practical suggestions on how to use them in preparing for advancement.

Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards

The Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, NAVPERS 18068-D, defines rates and ratings by describing the Navy's requirements for enlisted skills. The manual consists of two sections. The first section contains the occupational standards and naval standards that form the basis for what enlisted personnel are trained in and advanced upon. The second section contains the Navy Enlisted Classifications (NEC's) which were defined earlier in this chapter.

The naval standards contained in NAVPERS 18068-D express the minimum skills required of enlisted personnel which are not specifically rating oriented. For the most part they are stated as knowledge requirements because they represent basic things which should be known, and not necessarily done as a matter of routine. The occupational standards appear as task statements only since they define what enlisted personnel must do in their rate or rating. In other words, they are performance factors. The knowledge required to perform a task is inherent to the proper performance of the task.

Record of Practical Factors

Before you can take the Navywide examination for advancement, there must be an entry in your service record to show that you have met the naval and occupational standards for your rate and rating. The RECORD OF PRACTICAL FACTORS, NAVEDTRA 1414/1, is used for this purpose. Available for each rating, the form lists all performance factors, or task statements for the rating. As you demonstrate your ability to perform each factor, appropriate entries are made in the DATE and INITIALS columns. Space is provided on the form for entering additional performance factors or recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as occupational standards.

Until completed, the NAVEDTRA 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 performance 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 performance factors which have already been checked off.

Bibliography for Advancement Study

The Bibliography for Advancement Study, NAVEDTRA 10052 (revised) is important to all enlisted personnel preparing for advancement. It lists the rate training manuals and other publications prescribed for use by naval personnel concerned with training and advancement examinations.

NAVEDTRA 10052 is revised and issued yearly by the Naval Education and Training Support Command. Each revised edition is identified by a letter following the number. When using this publication be sure that you have the most recent edition.

If extensive changes in standards occur in any rating between the annual revisions of NAVEDTRA 10052, a supplementary list of study material may be issued in the form of a BUPERS Notice. When you are preparing for advancement, check to see whether changes have been made in the standards for your rating. If so, look for a BUPERS Notice that supplements NAVEDTRA 10052 for your rating.

The required and recommended references are listed by pay grade in NAVEDTRA 10052. If you are working for advancement to 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 NAVEDTRA 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 nonresident career 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 NAVEDTRA 10052 which lists the required and recommended references relating to the naval standards. Personnel of ALL ratings must complete the mandatory military requirements training manual for the appropriate level before they can be eligible to advance.

The references in NAVEDTRA 10052 which are recommended but not mandatory should also be studied carefully. ALL references listed in NAVEDTRA 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 NAVEDTRA number. You can tell whether any particular copy of a training manual is the latest edition by checking the NAVEDTRA number and the letter following this number in the most recent edition of List of Training Manuals and Correspondence Courses, NAVEDTRA 10061. (NAVEDTRA 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 NAVEDTRA 10052, the Naval Education and Training Program Development Center uses it as a source of questions in preparing the fleetwide examinations for advancement. In case of discrepancy between any publications listed in NAVEDTRA 10052 for a given rate, the examination writers 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. Look up the occupational standards for your rating before you study the training manual, and refer to them frequently as you study. Remember, you are studying the manual primarily in order to meet the standards.

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 occupational standards?

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 nonresident career courses whenever you can. As mentioned before, completion of a mandatory rate training manual can be accomplished by passing an NRCC based on the rate training manual. You will probably find it helpful to take other NRCC's as well as those based on mandatory manuals. Taking an NRCC 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 now will help you both now and later.

SOURCES OF INFORMATION

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 naval standards and occupational standards 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 SEABEES are listed in the NAVFAC Documentation Index, 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 mentioned in this chapter. Some additional publications that you may find useful are listed below.

Electrical Engineering, DM-4
Electric Power Distribution Systems Maintenance, MO-200
Advanced Base Electrical and Communication Systems, TP-PL-15

The Army publishes a number of technical manuals (TMs) relating to the field of the Construction Electrician. Among these are the following:

Electrical Power Transmission and Distribution, TM 5-765

Electrical Facilities, Substations, Repairs and Utilities, TM 5-680F
Electric Motor and Generator Repair, TM 5-764
Fundamentals of Telephony, TM 11-678

The National Bureau of Standards of the U.S. Department of Commerce publishes the National Electrical Safety Code as National Bureau of Standards Handbook H30. Section 1 of this work contains electrical definitions; section 9 contains rules covering methods of protective grounding. The remainder of the book consists of 5 parts, as follows:

Part 1.—Rules for the installation and maintenance of electrical supply stations.
Part 2.—Rules for the installation and maintenance of electric supply and communication lines.
Part 3.—Rules for the installation and maintenance of electric utilization equipment.
Part 4.—Rules for the operation of electric equipment and lines.
Part 5.—Rules for radio installations.

The Bureau of Standards issues from time to time a handbook which amends parts of Handbook H30. At the time of writing of this course, the latest amending handbook was Handbook 81, issued 1 November 1961, and containing a complete reissue of section 1 (definitions), section 9 (rules covering methods of protective grounding), and Part 2 (rules for the installation and maintenance of electric supply and communication lines).

Safety precautions applying to just about every type of construction are codified and issued by the Headquarters, Naval Material Command in Department of the Navy Safety Precautions for Shore Activities, NAVMAT P-5100.

Chapter 15 of NAVMAT P-5100 contains precautions which have particular application to electricity. General electrical precautions are contained in articles 1501 through 1503. Precautions relating to electrical equipment are given in articles 1510 through 1520. Article 1525 contains precautions to be observed when working on energized circuits. Precautions relating to line construction and distribution are in articles 1530 through 1535.

Many of the nonelectrical chapters of Safety Precautions for Shore Activities contain information of interest and concern to the Construction Electrician, such as chapter 3, "Materials Handling and Storage;" chapter 8, "Construction;" chapter 14, "Portable Tools;" and chapter 20, "Hazardous Materials."

You will also find safety precautions applicable to your rating in Naval Construction Force Safety Manual, COMCBPAC/COMCBLANT Instruction 5100.1 series.

MANUFACTURERS' MANUALS

When new equipment is procured by the Navy, it usually is accompanied by a manual of operating, maintenance, and installation instructions. These manuals should be kept readily available for reference. They describe in detail the procedures for installing, maintaining and operating a specific piece of equipment.

Study the manuals. Take care of them. Do not lose or damage them. When you are required to repair a piece of equipment, follow the manual's instructions carefully.

COMMERCIAL PUBLICATIONS

A wealth of information on electrical construction exists in various reports, pamphlets, handbooks, and textbooks prepared by manufacturers, trade associations, technical and professional societies and other sources. Much of this literature is available in station libraries, Public Works Departments, and battalion offices and libraries.

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, published in July 1971. Copies may be ordered in accordance with the Navy Stock List of Forms and Publications, NAVSUP 2002. Supplements to the Film Catalog are issued periodically.

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. A film that is obsolete only in part may sometimes be shown effectively if, before or during its showing, procedures that have changed are pointed out to the viewers.

CHAPTER 2

SAFETY

All electrical systems are potential KILLERS. Personnel should be aware of the potential danger. CE's especially should have complete knowledge of the inherent and manmade electrical hazards because they WORK on electrical equipment or systems. But safety applies not only to electrical equipment or systems, but to the entire construction field and its hazards which are always present.

In this chapter, we will examine some of these hazards and provide proven ways of protecting yourself and others against them. By adhering to safe working practices, you will minimize danger to life and equipment. Furthermore, by learning first aid and how to apply it correctly, you may be able to save omeone's life.

ACCIDENT PREVENTION

Accident prevention depends on your knowing the appropriate safety factors for a given hazardous condition, on your ability to recognize a condition as hazardous. Conditions change from job to job and from day to day on the same job, so you must be constantly alert to the possibility of new hazards. Whenever you observe a safety hazard, even though you may not be involved in the work being done, call it to the attention of a responsible person. Make a prompt report of any unusual condition, whether in a generating station, a substation, an underground or overhead cable system, or any electrical equipment. Unusual conditions are frequently the forerunners of a break in continuity of service, and they usually increase the hazard level. When they occur the best procedure is to take immediate protective steps, rather than wait until it is obvious that a hazard has developed.

ELECTRICAL SHOCK: CAUSES AND CONSEQUENCES

Most fatal electric shocks do not happen to the uninitiated—they happen to people who should know better. As a CE, carelessness in your work can sentence you to death by electrocution. Familiarity with the equipment tends to make you forget the little precautions taught in trade school.

Unfortunately, it is impossible to bring the dead back to life or change the results of the accident; that is why it is necessary, even at the risk of monotony, to constantly stress or even preach SAFETY. It may make you think twice before taking that last chance.

Most of us are apt to remember only the most important safety precautions, but how many of us stop to think of the small details that really ENSURE safety? Also, how many of us realize it is the current, not the voltage, that is lethal?

Although the sign CAUTION — HIGH VOLTAGE serves as a reminder to keep hands off, don't forget that an electric shock from 10,000 volts is no more deadly than a shock from ordinary 115-volt house current. Industrial equipment using as little as 42 volts of direct current has been fatal (30 volts a-c is considered hazardous). CURRENT, NOT VOLTAGE, IS THE LETHAL AGENT.

The seriousness of an electric shock depends upon the magnitude of the current flow in the victim. Current flow, in turn, depends upon the electrical resistance of the circuit path through the victim's body. This can vary considerably depending upon the degree of contact and the skin resistance at the time of contact.

We are all aware of the presence of moist skin caused by perspiration on a hot day, but few of us think about the sudden moistening of the skin when we are frightened or startled. The unexpected discharge of a capacitor or the inadvertent shorting of a voltage point when troubleshooting often will startle the technician, make him jump, and at the same time bring on a momentary cold sweat. Such reactions are not uncommon, and obviously they set up a shocking situation.

Although this may be considered an extreme case, it does illustrate how an individual's resistance can vary considerably from minute to minute, depending upon his emotional state at the instant of contact. Skin resistances of a few hundred ohms when wet, to well over 500,000 ohms when dry, have been measured, so be careful—take every safety precaution possible—it may save your life.

Figure 2-1 illustrates what a person may expect when he is subjected to increasing (current) electric shock. His first reaction occurs when the current is only 2- or 3- milliamps. At 10 milliamps, the shock is no longer a mild tingling sensation but becomes painful. As the current flow increases beyond 20 milliamps, muscular paralysis begins and the victim cannot release the contact. In the range from 50 to 100 milliamps, breathing becomes difficult—in fact it often stops. Between 100 and 200 milliamps, ventricular fibrillation (uncoordinated twitching) of the heart occurs. This is usually fatal. Above 200 milliamps severe burns will be produced, a sickening odor occurs, and the muscular reaction of the heart is so severe that it "clamps." The clamping prevents damaging ventricular fibrillation and the victim's chances of survival are good if help is immediately available.

Unfortunately it is impossible to tell whether an unconscious victim has received a fatal shock, so artificial resuscitation must be applied immediately if breathing has stopped. Do not stop efforts at resuscitation until medical authority pronounces the victim beyond help. Victims have been known to revive after 8 hours of artificial resuscitation.

If this description of the effects of shock sounds gruesome, remember that being aware of the possibility of very serious consequences will remind you to take every safety precaution available to avoid such eventualities.

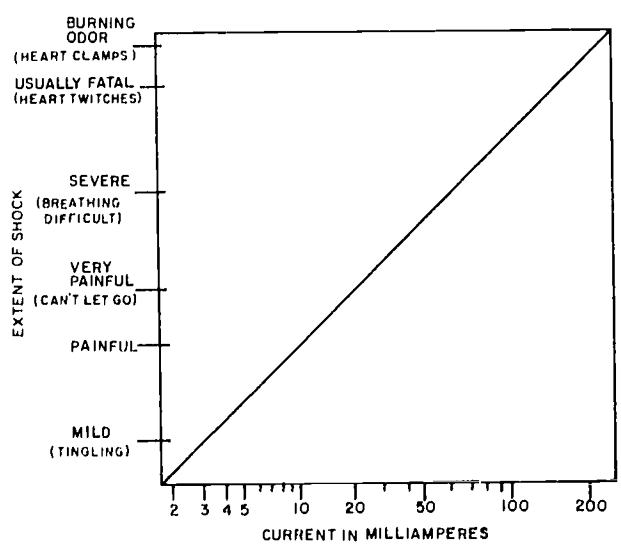
SAFE WORKING PRACTICES

When working with or around electrical equipment, don't wear loose clothing with metal buttons or metallic ornaments—they may come into contact with a live circuit and cause the wearer to flinch and come into bodily contact with exposed live parts. Remove rings, wristwatches, and metal identification bracelets and store them in a safe place (not in your pocket).

Don't examine live equipment when mentally or physically fatigued. Use rubber gloves, fuse tongs, and other safety tools and stand on a safety mat. Wear safety footwear.

Familiarity with the equipment is no excuse for taking chances. If you must work on hot equipment, don't work alone. It takes only an instant for a person to get injured and it may take minutes before the victim is discovered. Those minutes can mean the difference between life and death.

If you discover an accident victim, don't waste valuable time looking for the power switch. Use a rope, a dry length of wood, your belt, or other insulating material to pull the victim loose. The resistance of the victim's body decreases with time, and a delay in getting him loose can prove fatal.



27.314

Figure 2-1.—Electrical shock scale.

If at all possible, work on open or dead circuits. Lock and tag the power switch in the OPEN position, particularly if the switch is not in the area in which you are working. Rope off and place danger signs in hazardous areas.

Consider all circuits alive until they are proved otherwise. NEVER use your fingers to check the line; use a meter. When measuring over 300 volts, don't hold the test prods. Pull the power, clip the meter leads in place, and turn on the power. It takes longer, but it's worth it.

Don't forget to discharge large capacitors after the equipment has been turned off. Discharge them not once but twice for at least 5 seconds. A charged capacitor can pack a real wallop. Use a suitable insulated shorting or grounding bar.

Ensure that equipment is adequately grounded. Don't bridge a fuse or interlock.

Finally, do not relax caution just because protective measures have been taken. No safeguard is 100 percent effective.

LIFTING SAFELY

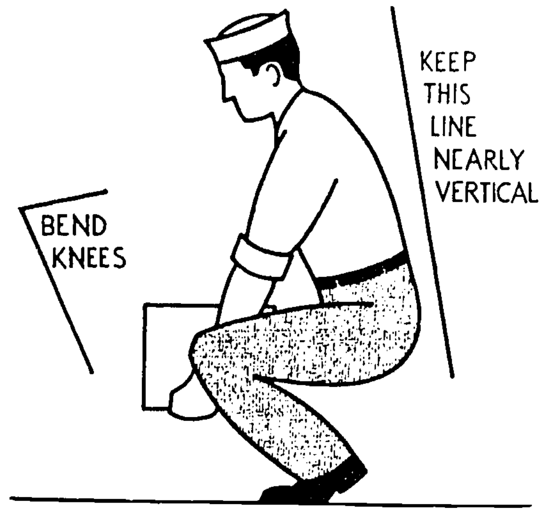
Look over the object to decide the best way to hold it. Place your feet close together and close to the object to be lifted. Get a good grip on the load. Bend your knees and keep your back straight (fig. 2-2). Keeping your body upright, lift with the leg and arm muscles, not with the back and stomach. Get a good footing and crouch when starting to lift. Take a deep breath and hold it while lifting or lowering a load.

Test the load first, lifting gradually. Avoid jerky motions and keep the load close to your body. Avoid twisting motions and don't shift positions of the feet while making the lift. Be sure you can see past the load and get help for large or heavy objects.

FIRE SAFETY

Gasoline should be kept in safety containers. Flammable cleaning fluids should not be used on electrical apparatus.

Be sure that fires are out when pots and torches are not in use.



90.22

Figure 2-2.—Lifting heavy material.

Closed containers should be provided for greasy rags.

Temporary wiring should not be strung over makeshift supports.

All circuits should be fused properly. You must abide by the rules for each hazardous location.

Know the proper fire extinguishers to use, particularly on electrical fires. A Class C extinguisher is preferred since it is nonconductive and can be directed against energized circuits without danger of shock.

MEMORIZE YOUR BASE FIRE TELEPHONE NUMBER. In case of fire, immediately deenergize the circuit affected. Call the Fire Department. Control the fire insofar as possible until firefighting personnel arrive.

WALKING SAFELY

It is safer to walk around trenches or other excavations than to jump over them or walk over an unsafe plank. Where hoisting or overhead work is being done, keep away from unprotected areas so you will not be struck by falling or swinging materials.

Look where you are going so you won't trip over materials or step on nails. In wet weather, be extra sure of your footing where walkways or platforms may be slippery.

HANDTOOL SAFETY

Do not use makeshift tools. Most electrical tools are specialized. For example, hot-line tools are necessary to ensure uninterrupted service. Use them correctly and do not use substitutes.

Keep all cutting tools sharp. They are safer sharp. See that jaws of wrenches are in good condition.

Tool belts should be kept in good repair for your own protection as well as for the protection of men working under you. Make sure that handles of all tools are not cracked or otherwise damaged.

LADDER SAFETY

Before climbing a ladder, make sure it is in good condition, with no cracked, split, or patched side rails, rungs, or cleats. Check the ladder to see that it is placed with the base set out one-fourth the ladder length and set firmly so it won't tip or slip. See that the top of the ladder extends at least 3 feet above the platform for a handhold to get on and off safely, and is resting firmly or tied to a support.

Use both hands for climbing. If you must carry tools, put them in a bag slung over your shoulder.

Do not use metal ladders while working around hot lines or equipment. Avoid contact with metal parts of wooden ladders.

Move the ladder when necessary. Do not try to overreach.

INSTALLATION SAFETY

Be sure of overcurrent protection since proper size wire and fuses may save a life or building. You must also be sure that temporary wiring is installed as safely as permanent wiring.

Portable tools and machines must be grounded for the protection of everybody. Be sure that flexible cords are protected as much as possible and are in good condition.

PERSONAL SAFETY

- Horseplay can result in death.

- Be sure to ground deenergized lines before performing work.

- Before energizing a line, doublecheck to make sure that everything and everyone is clear.

- Wherever possible in your work on live electrical equipment use only one hand and have a rubber glove on each hand.

- Goggles should be worn when pouring acid and when performing grinding, drilling or soldering operations.

- Know artificial respiration (discussed later).

WEAR HARD HATS

Regular protective helmets (hard hats) must provide the necessary insulation resistance so that personnel other than electrical workers will be protected from accidental head contacts with electrical circuits and equipment at comparatively low voltages (less than 2200 volts). Electrical workers requiring head protection incidental to their duties or to the working environment, particularly those engaged in transmission or distribution line installation and repair, must wear electrical worker's insulating safety helmets or all-purpose protective helmets for which the proof-test voltage is not less than 20,000 volts. The hat shown in figure 2-3 saved one man's life. Will use of a similar one save yours?

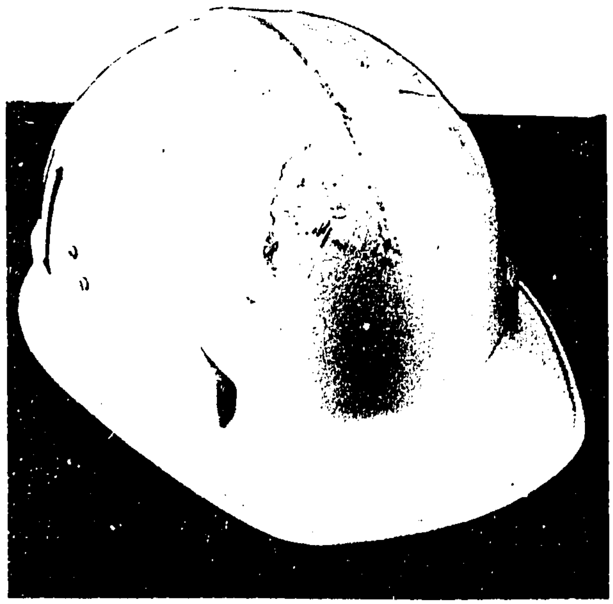
Despite the fact that most head injuries are serious, there are some workers who seem reluctant to wear hard hats. Everyone should take advantage of such valuable protection as the hard hat. Men give various reasons for refusing to wear these hats. Here are some of the common objections and reasons they do not hold true.

Objection: TOO HEAVY

Justification: Hard hats are a few ounces heavier than conventional headgear, but the extra protection is worth the extra weight. Actually, a hard hat is less than one-third the weight of an Army helmet and liner.

Objection: TOO HOT

Justification: On a hot summer day with the temperature above 100°, it may not be as comfortable as you'd like, but it is still 3° to 9° cooler than inside an ordinary hat.



26.203
Figure 2-3.—Hard hat saves man's life. Will use of a similar one save yours?

Objection: TOO COLD

Justification: Could be, but the problem is solved by wearing a winter liner. It'll keep head, neck, and ears warm without lessening the protective value.

Objection: CAUSES HEADACHES

Justification: There's no medical reason why PROPERLY ADJUSTED hard hats would bring these complaints. More than likely there's another reason such as hunger, thirst or eyestrain.

Objection: WON'T STAY ON

Justification: In a high wind, you'll need a chinstrap on your hard hat. Normally, however, that hat will stay on despite a lot of stooping and bending you may do in your work.

Objection: AMPLIFIES NOISE

Justification: Not at all. In fact, tests show that properly worn hard hats have a shielding effect on the wearer's ears. Noises are not intensified by the hat.

ELECTRICAL SAFETY REFERENCES

You must recognize that it is impossible to supply a complete list of electrical safety precautions in this manual. A number of invaluable references relating to safety are as follows:

SAFETY PRECAUTIONS FOR SHORE ACTIVITIES, NAVMAT P-5100. This reference book by Headquarters, Naval Material Command of the DEPARTMENT OF THE NAVY is an excellent guide which disseminates safety precautions known to be instrumental in preventing accidents and in maintaining a safe working environment. Chapter 15 is devoted to electrical and electronics safety. Ask your Chief Construction Electrician to let you look it over at battalion headquarters. He is sure to have it there. Knowledge of the contents of this chapter is a prerequisite for promotion to the senior levels.

NATIONAL ELECTRICAL CODE. This book, by the National Fire Protection Association, is modified and published every 3 years. It contains basic minimum provisions considered necessary for safety from electrical hazards of personnel and buildings. Requirements for electric conductors and electric equipment utilized in a variety of areas are covered. Many Navy specifications are based on these minimum requirements.

NATIONAL ELECTRICAL SAFETY CODE. This code is published by the U.S. Department of Commerce's National Bureau of Standards and should not be confused with the one described in the preceding paragraph. Handbook H-30 is another title for this book. It discusses methods of protective grounding of circuits, equipment, and lightning arresters for stations, lines, and utilization equipment. Additionally, rules for installation, operation, and maintenance of electrical supply stations and equipment, and electrical and communication lines are spelled out. Portions of this text have been superseded by National Bureau of Standards Handbook H-43.

INSTALLATION AND MAINTENANCE OF ELECTRIC SUPPLY AND COMMUNICATIONS LINES SAFETY RULES AND DISCUSSION. This publication, Handbook H-43, of the National Bureau of Standards has superseded portions of the National Electrical Safety Code related to the installation and maintenance of electric supply and communication lines. Much engineering data included in this text is useful to Construction Electricians.

SAFETY RULES FOR THE INSTALLATION AND MAINTENANCE OF ELECTRIC SUPPLY AND COMMUNICATION LINES. National Bureau of Standards Handbook 81 supersedes parts of the above listed handbooks. It is imperative that you use the latest rules and regulations in your work to minimize safety hazards.

ELECTRIC SHOCK, ITS CAUSES AND PREVENTION. This 37—page text, NAVSHIPS 250-660-42, contains vital information extremely valuable to all personnel who use electric appliances or who work around electrical equipment. It describes a variety of causes and preventions for shock. It is normally available in the battalion office or the library of the base to which you are attached. Be sure to read this manual since complete understanding of the information presented may save your life.

CLEANING

Electrical and electronic equipment must be kept clean at all times to ensure proper performance. Brushes, dusters, brooms, or other such articles which may be used within 4 feet of or on electrical equipment having exposed or current-carrying parts should not themselves contain any exposed metal parts. If a vacuum cleaner is necessary, use only with a nonmetallic hose and an adequate dust receiver.

Use only rubber or insulating hose in air lines for blowing out equipment. Use no more than 10 pounds of pressure to avoid damage to the insulation and injury to personnel. Be sure the air is free from water. Never turn compressed air on yourself or others, since it can cause serious injury.

Use sandpaper and files only upon competent advice. Emery paper should never be used on electrical equipment because of the conductive residue remaining after use.

SAFETY EQUIPMENT

Do not work on electrical apparatus with wet hands or while wearing any wet clothing. When performing work on or within 4 feet of exposed electrical equipment, do not wear any clothing with exposed zippers, buttons, or other metal fasteners, or loose or flapping clothing. Take no chances; dress appropriately. Obviously, flammable articles, such as celluloid cap visors, should not be worn. Personnel should remove rings, wristwatches, bracelets, and other similar metal items before performing work on or within 4 feet of electrical equipment with exposed current-carrying parts.

Men performing line construction and maintenance work should wear high-cut shoes with sewed soles for work on live electrical circuits above 50 volts. Thin-soled shoes and shoes with metal plates or hobnails are prohibited. Safety shoes with nonconductive soles should be worn, if available.

Keep all insulating and protective devices stored flat, and free of oils, chemicals, and other materials.

Air-test rubber gloves daily before starting work on live conductors or equipment. Testing is done by grasping the cuff of the rubber glove at opposite points and twirling (fig. 2-4). While the end is closed with one hand so the air cannot escape, squeeze the glove to force air into thumb, fingers, and palm. Hold the glove to your ear to listen for escaping air, making a thorough visual inspection for holes and thin spots, or hold the glove under water and check for air bubbles. If it is defective, tag it and turn it in for replacement.

When cutting holes in masonry material, or performing grinding or drilling operations, wear safety goggles.

Wear a hard hat—especially when working under other workers or in close quarters.

Body belts and safety straps should be inspected before each use.

Be sure that gaffs on climbers are properly sharpened. When gaffs are shorter than 1-1/4 inch, replace them.

Do not put rubber gloves or other rubber protective equipment in containers with tools.

No work should ever be done on live conductors of any voltage except in case of emergency. If the work requires that one hand be free of covering, a rubber glove should be worn on the other. Personnel intending to work on live circuits, or on equipment containing exposed current-carrying parts where the voltage is greater than 30 volts, should put on rubber gloves before coming within reach of the live parts, and should not remove the gloves until entirely clear of such equipment. Rubber gloves should not be used for any purpose except live-line electrical work.

Leather protectors should always be worn over rubber gloves and should not be used for any purpose other than with rubber gloves.

Rubber sleeves or rubber gloves should never be rolled down or worn inside out. Under no circumstances should two pairs of rubber gloves be used.

Personnel should wear rubber gloves when cutting a supposedly dead cable, or testing supposedly dead cable, or testing supposedly burned-out transformers.

TESTING RUBBER PROTECTIVE EQUIPMENT

Rubber gloves and other rubber protective equipment should be laboratory tested at intervals not to exceed the following when in regular use except as described later:

Rubber Gloves	30 days
Rubber Blankets	90 days
Rubber line hoses and hoods	180 days

In addition, before each use, they should be checked by the user for punctures, tears, or abrasions. Gloves should be air-tested. If there is evidence of any leakage or thin spots, the gloves should not be used. Electrical tests, testing equipment, and method of marking should be in accordance with current American Society for Testing and Materials (ASTM) standards. Each glove or other piece of rubber protective equipment should be marked with the last date tested. Items failing to pass the test should be replaced. Tests should be made by naval activities having the necessary equipment, by reputable electrical testing laboratories, or by local power companies which may have testing equipment and are willing to perform the tests.

All rubber protective equipment should be given a thorough visual inspection and electrical test whenever the last test was made more than 6 months prior to issue or delivery for actual use of personnel. Equipment maintained in a standby status for emergency use only may be considered to be in the same category. If it has been used more than 6 weeks, but less than 6 months, after the last test, it should again be tested before being returned to standby status or placed in regular use.

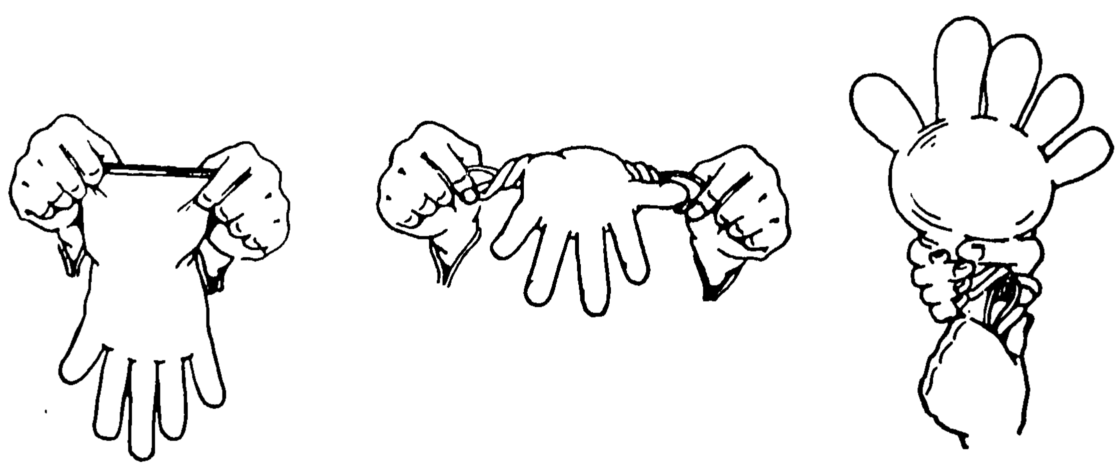


Figure 2-1.—Testing rubber gloves. 73.274

INSULATING FLOOR COVERING

On all circuits where the voltage is in excess of 30 volts, the men should be insulated from accidental grounding by use of approved insulating material on the floor at operating and working locations. The material must have the following qualities:

It should be dry, without holes, and must not contain conducting materials. The voltage rating for which it is made should be clearly marked on the material, and the proper material must be used so that optimum protection from the voltage can be supplied.

On voltage below 600 volts, dry wood may be used, or, as an alternative, at least two layers of dry canvas, sheets of phenolic material, or rubber mats. Where other than approved rubber mats are used, the marking provision of the paragraph above does not apply; however, care must be taken to ensure that substitute material is capable of providing the required insulation value.

On circuits above 600 volts, nonconducting rubber matting of an approved type should be used.

Exercise care to ensure that moisture, dust, metal chips, and so on, which may collect on insulating materials are removed at once. Small deposits of such materials can become hazardous.

PLATFORMS

Whenever it is necessary to work on electrical circuits or equipment in wet or damp locations, dry wooden (or similar nonconducting material) platforms should be provided so that there will be no possibility of contact between the wet floor and the workmen's shoes.

TOOLS

Shop machinery and handtools are frequently overlooked sources of danger to personnel. Because of their familiarity and use in everyday applications, we lose sight of their potential danger. Let's examine them.

One source of danger that often is neglected or ignored is the use of handtools which are no longer considered serviceable. Tools having plastic or wooden handles that are cracked, chipped, splintered, or broken may result in injuries to personnel from cuts, bruises or particles striking the eye. Such tools should be condemned, replaced, or if at all possible, repaired, before they cause accidents.

Another source of danger that often is neglected or ignored is the unsafe work practice of covering the metal handle of a tool with a layer of friction tape, or with a cambric sleeving, to form an improvised insulated tool. This practice does not afford an adequate insulating barrier to protect personnel from dangerous voltages; therefore, steps should be taken to ensure that this unsafe practice is not permitted.

In an emergency, when it is necessary to improvise an insulating barrier between the tool and the individual's hand, an approved method is first to apply several layers of approved rubber insulating tape (half lapped), or insulating tubing removed from scraps of electrical cable, to the metal surface areas to be covered. Then apply a layer or two of friction tape over the insulating material. In this manner, an adequate insulating barrier is provided and the possibility of accidental contact with a lethal voltage is minimized.

As a general precaution, be sure that all tools conform to Navy standards of quality and type. Use each tool only for the purpose for which it is intended. All tools in active use should be maintained in good repair and all damaged or nonworking tools should be returned to the toolkeeper. Do not leave tools on floors, platforms, ladders, or on shelves above moving machinery. Keep tools and hands free of grease, and clean tools with an approved solvent. Tools and other materials should not be thrown or dropped down to personnel working on another level. They are to be raised or lowered by means of handlines or canvas toolbags or buckets. Men should stand clear when tools and other materials are being raised or lowered.

Care must be taken when selecting pliers, side cutters, or diagonal cutters. Pliers or cutters should never be used on nuts or pipefittings. Teach your men to always hold the pliers or cutters so that the fingers are not wrapped around the handle in such a way that they can be pinched or jammed if the tool slips. When cutting short pieces, take care that parts of the work do not fly and cause injury. NEVER PUT EXTENSIONS ON TOOL HANDLES TO INCREASE LEVERAGE.

When selecting a screwdriver for electrical work, be sure that it has a nonconducting handle. The screwdriver selected should be of the proper size to fit the screw and should never be used as a substitute for a punch or a chisel. The blades of screwdrivers can be kept in proper shape with a file or a grinding wheel.

Use wrenches only if they are right for the job and only if they are in good condition. An adjustable wrench should be faced so that the movable jaw is located forward in the direction in which the handle is to be turned.

Remember to use goggles whenever the danger of flying debris exists or in any grinding operation.

Grease must be handled carefully and used only for the purpose intended. Serious injury has resulted when grease has been shot out of a grease gun in horseplay; NEVER point the gun toward another person.

Powder-actuated Tools

Powder-actuated tools should be operated, repaired, serviced, and handled only by personnel who have been trained and certified by the manufacturer, his authorized representative, or Navy Department certified instructors. In applications to concrete, approval for use of the tool should be given only after it has been ascertained that it will give satisfactory results and cause no spalling or shelling out.

As the operator of a powder-actuated tool, observe the following safety precautions:

Do not operate in an explosive or inflammable atmosphere, or in an area where nonsparking tools are required.

Whether loaded or unloaded, never point the tool at yourself or other persons; keep it pointed in a safe direction.

Before starting a day's work, check the bore of the barrel to be sure it is free of any obstruction. Failure to clean the bore may damage the barrel beyond repair. Never clear the bore by firing a powder charge. Use a piece of wire or rod.

Never carry a loaded tool away from the immediate jobsite. Be sure the tool is unloaded when not in use. Unload the tool if your work is interrupted after loading.

Be sure the tool is held perpendicular to the work surface.

Use the right guard for the job. Special guards are used where recommended.

Never attempt to drive a stud through a predrilled or prepunched hole in fixtures or material without a special guard designed for this type of operation.

In case of misfire or failure to fire, do not remove the tool from the working surface for at least 15 seconds. Open the tool and remove the powder charge BEFORE removing the guard from the work surface.

Never attempt to drive studs into very hard or brittle materials, including but not limited to cast iron, glazed tile, surface hardened steel, glass block, thin slate, live rock, face brick, or hollow tile.

When anchoring fixtures or any structural material to a concrete, steel or other subsurface suitable for stud driving, be sure there is no void or air space between the fixtures or structural material and subsurface. When working on precast concrete block, be sure to drive studs so they penetrate a wall between the cells. Lower holding power will result if studs are driven at hollow cell locations.

Never attempt to drive a stud closer to the edge of structural materials than the distance recommended by the manufacturer.

Never use the tool in material or surfaces which may be completely penetrated by the stud.

The tool operator, together with other personnel in the vicinity, should wear safety goggles or other approved safety-type face and eye protective devices and a hard hat.

CAUTION: The powder-actuated tool uses powder-loaded cartridges in its operation. Check first when handling to determine if it is loaded.

Soldering

One sizzling burn experience is usually enough to breed a healthy respect for hot objects. Many of these experiences occur during welding operations and the use of such items as soldering irons, lead pots, torches, and the fixtures used to brace, clamp, or hold them. To avoid the risk of scalding or charring your flesh, don't leave molten material or heated objects unattended. Display HOT HAZARD signs if you must leave; and return as soon as possible. Use tongs, hooks, or other protective devices to handle hot pots and pieces of stock. If there is any chance of spatter from hot flying particles, be sure to use goggles.

Soldering Irons

When using a soldering iron, bear in mind the following:

Electric soldering irons must not remain connected longer than necessary and must be kept away from flammable material.

To avoid burns, always assume that a soldering iron that is plugged in is hot.

Never rest a heated iron anywhere but on a metal surface or rack provided for this purpose. Carelessness on your part could result in fire, extensive equipment damage, and serious injuries.

Never swing an iron to remove solder because the bits of solder that come off may cause serious skin or eye burns or ignite combustible materials in the work area.

When cleaning an iron, use a cleaning cloth, but DO NOT hold the cloth in your hand. Always place the cloth on a suitable surface and wipe the iron across it to prevent burning your hand.

Hold small soldering jobs with your pliers or a suitable clamping device. Never hold the work in your hand.

It is not so obvious, but the power supply should always be disconnected from the equipment needing to be worked on, to prevent serious burns from contact with high voltages.

After completing the task requiring the use of a soldering iron, disconnect the power cord from the receptacle and, when the iron has cooled off, stow it in its assigned storage area.

SHOP MACHINERY

In your work as a Construction Electrician, you may be required to use shop machinery such as a power grinder or a drill press. In addition to the general precautions on the use of tools, there are several other precautions which should be observed when you work with machinery or assign men to operate it. The more important ones are:

Never operate mechanical or powered equipment unless you are thoroughly familiar with its controls. When in doubt, consult the appropriate instructions or ask someone who knows.

Always make sure that everyone is clear before starting or operating mechanical equipment.

Never try to clear jammed machinery without first cutting off the source of power.

When hoisting heavy machinery (or equipment) by a chain fall, always keep everyone clear, and guide the hoist with lines attached to the equipment.

Never plug in portable electric machinery without ensuring that the source is the kind of electricity (a-c or d-c) called for on the nameplate of the machine.

Drills must be straight, undamaged, and properly sharpened. Tighten the drill securely in the chuck using the key provided; never secure it with pliers or with a wrench. It is important that the drill be set straight and true in the chuck. The work should be firmly clamped and, if of metal, a center punch should be used to score the material before drilling is started.

Be sure that power cords do not come in contact with sharp objects. The cords should not be allowed to kink, nor should they be allowed to come in contact with oil, grease, hot surfaces, or chemicals. When cords are damaged, they should be replaced instead of being patched with tape.

USE OF WARNING SIGNS, PLATES, AND TAGS

Warning signs and suitable guards should be provided to prevent personnel from coming into accidental contact with dangerous voltages, to warn personnel of the possible presence of explosive vapors, to warn personnel working aloft of poisonous effects of stack gases, and to warn of other dangers which may cause injuries to personnel. Equipment installation should not be considered complete until assurance has been made that appropriate warning signs have been posted in full view of operating personnel.

Certain types of standard electronics warning signs are available for procurement. A list of signs that are available has been distributed to all ships, commands, and shore activities. Any warning signs not listed should be ordered on a separate requesting document. Drawings of the standard warning signs most frequently used have been prepared by the Naval Ship Systems Command.

High Voltage Warning Sign, NAVSHIPS Drawing No. RE 10 B 608B (fig. 2-5) is to be displayed at all locations where danger to personnel exists, either through direct contact with high voltage or through high voltage arc over. Appropriate guards should also be installed at these locations.

Warning Sign for Personnel Working Aloft in Way of Smoke Pipe Gases, NAVSHIPS Drawing No. RE 10 AA 529A is to be displayed at the bottom and top of access ladders to electronic and electrical equipment in the way of smoke pipe gases (fig. 2-6).

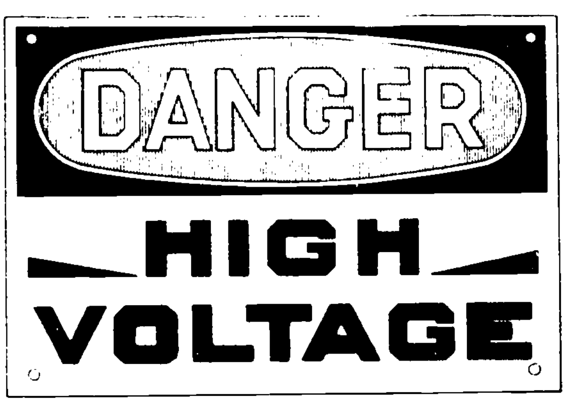


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Figure 2-5.—High voltage warning sign.

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Figure 2-6.—Smoke pipe gases warning sign.

Warning signs should be temporarily displayed where explosive vapors are present in any compartment or space. No electrical or electronic equipment or auxiliary control units should be energized with areas where these signs are posted. Explosive Vapors (RE 10 A 589A) is such a sign.

Warning tags requiring open-circuit condition should be placed on all necessary power supply switches to prevent accidental application of power to units of an electrical or electronic system that are under repair or overhaul.

Warning tags, NAVSHIPS 3950(3-63), for marking open position of switches and cutout circuits (fig. 2-7), are used to indicate switches which must be left in the OFF or OPEN (safe) position during repairs. These tags are available for ship and shore personnel through normal supply channels.

Appropriate warning signs should be displayed in electrical, aviation, electronic, and special weapons shops. Danger or warning signs should be permanently posted in conspicuous places and suitable guards should be installed in appropriate areas to prevent personnel from making accidental contact with antennas, antenna leads, power supply leads or terminals, fuses, or any uncovered contacts that have sufficient voltage and current characteristics to constitute a hazard to personnel. (See figs. 2-5 and 2-6.)

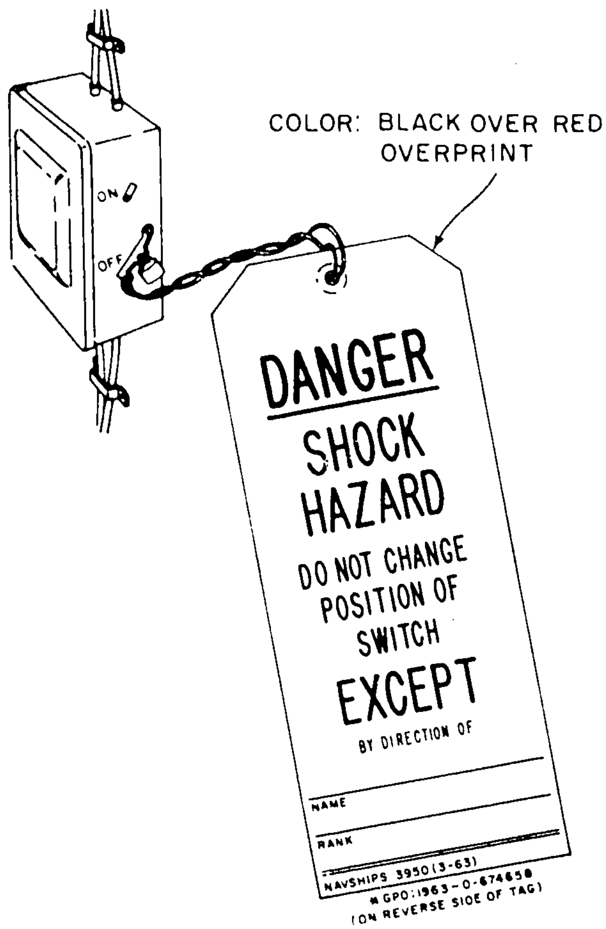

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Figure 2-7.—Warning tag.

GROUNDING

Metal cases, bases, frames, and other metal parts of electrical equipment, appliances, machines, and fixtures powered from supply circuits in excess of 30 volts a-c or d-c should be grounded. Where inherent grounding is not provided by the mounting arrangements, ground connections should be provided to ground the frame, enclosure, or support of permanently installed electrical equipment. Semiportable equipment which is normally used at fixed location should also be grounded. Portable electrical equipment in conductive housings should have adequate grounding.

A July 1, 1968 amendment to the specifications for electrical and electronic workbenches makes it mandatory to have a 1-foot ground lead for every 4 feet of workbench.

The grounding conductor should have a cross sectional area at least equal to, and preferably greater than, the cross sectional area of the line conductors which carry power to the equipment. The grounding conductor should make positive metal-to-metal, low resistance contact with the equipment at one end and at the other end with the metal object used as a ground, the hull of the ship in shipboard installations, and the ground rods, water pipes or installed grounding object in shore installations. The resistance between the earth and the metal object used as ground should not exceed 3 ohms.

Grounding should be checked at regular intervals after repair work has been performed, and be in accordance with the National Electric Code. Never open ground connections at ground pipe or at ground bus bars unless they first have been disconnected at the point of contact with the equipment they are intended to ground. This prevents an accident if the ground wire or bus bar should become energized. Whenever a ground wire on a pole is to be connected, make the ground pipe connection first.

DANGER FROM METAL OBJECTS

Personnel should exercise care when it is necessary to walk above open electrical equipment or exposed wires to ensure against dropping or loss of metallic objects attached to clothing.

Tools of magnetic material can be pulled into contact with dangerous circuits when these tools are used in the vicinity of electrical circuitry. Care must be taken to avoid this hazard.

INTERLOCKS AND SAFETY DEVICES

Safety devices such as interlocks, overload relays, and fuses should not be altered or disconnected except for replacement, nor should safeguard circuits be modified without specific authority.

PAINTING ELECTRICAL EQUIPMENT

Special precautions are necessary when removing paint or repainting electrical equipment. In general, the removal of paint from electrical equipment should be avoided. The use of scraping or chipping tools on such equipment is liable to injure the insulation or damage delicate parts. Furthermore, paint dust is composed of abrasive and semiconducting materials which impair the insulation. All electrical equipment, such as generators, switchboards, motors, controllers, and so on, should be covered to prevent entrance of the paint dust when paint is being scraped in the vicinity. After completion of the paint removal, the electrical equipment should be thoroughly cleaned, preferably with a vacuum cleaner, if available.

Repainting of electrical equipment should be done only when necessary to prevent incipient corrosion. The painting should then be confined to the area affected. General repainting of electrical equipment or enclosures for electrical equipment for the sole purpose of improving their appearance is not desirable. Paint should never be applied to any insulating surfaces in electrical equipment. Common sense tells you not to paint over identification plates.

PROTECTION OF NONELECTRICAL WORKERS

An insulating barrier should be provided between the work area and any live electrical parts; or the circuits should be deenergized where work is being performed within 4 feet from the exposed parts of electrical or electronic equipment by painters, carpenters, or other trades, regardless of the voltage. In all such cases, the supervisors of the nonelectrical workers should report the location of the work to the Construction Electrician in charge. The Construction Electrician should instruct the supervisors of nonelectrical workers regarding proper precautions against electrical hazards, and provide proper insulating barriers, or provide for deenergizing and locking out of circuits where possible. The supervisor of the nonelectrical workers is responsible for carrying out precautionary instructions given by the Construction Electrician in charge.

NEW INSTALLATIONS

New installations should comply with applicable rules and regulations in the National Electric Code. For example, electric light pull chains and keyed metal sockets must be of the insulated type.

ELECTRICAL SAFETY PRECAUTIONS

The safe working practices discussed so far in this chapter are applicable not only to the electrician, but to anyone working in the construction field. In addition to these general safety precautions, there are safety rules that apply specifically to electrical equipment. Here are some safety suggestions to follow when you are working on electrical tools and appliances and energized circuits.

PORTABLE EQUIPMENT

Portable electrical cables should be carefully selected and maintained. Spliced portable cables are extremely dangerous and should never be used unless an emergency warrants the great risk involved. Portable cables should be of sufficient length that they will not be subjected to longitudinal stresses or need to be pulled taut to make connections. Current-carrying capacity should be ample for all expected power demand. Portable cables should be checked frequently while in service to ascertain degree of heating. Any cable which feels more than comfortably warm to the bare hand placed outside the insulation should be checked immediately for overloading. Interconnections between lengths of portable cable should be made only on approved connection blocks or by approved fittings which should be suitably insulated and enclosed to eliminate all possible hazards from fire or shock to personnel.

PORTABLE POWER TOOLS

The hazards associated with the use of portable power tools are similar to stationary machines and include electrical shock, bruises, cuts, particles in the eye, falls, explosions, fires, and so on. Safe practice in the use of these tools will reduce or eliminate such accidents.

All portable power tools should be inspected before use to see that they are clean, well oiled, and in the proper state of repair. The switches should operate normally, and the cords should be clean and free of defects. The metal case of any electrically driven power tool should be well grounded. Sparking electric tools should never be used in places where flammable gases or liquids or exposed explosives are present. The power should always be disconnected before accessories on a portable tool are changed.

Inspect the cord and plug for proper connection. Do not use any tool that has a frayed cord or broken or damaged plug. Always connect the cord of a portable power tool into the extension cord before the extension cord is inserted into a live receptacle. Always unplug the extension cord from the receptacle before the cord of the portable power tool is unplugged from the extension cord. See that all cables are positioned so that they will not constitute tripping hazards. Wear eye protection when working where particles may strike the eyes.

After completing the task requiring the use of a portable power tool, disconnect the power cord as described above, and stow the tool in its assigned location.

PORTABLE PERSONAL EQUIPMENT

Personal radios, television sets, record players, and wire or tape recorders having metal cases or metal back or bottom are a safety hazard in many cases. In much of this type of equipment, the chassis forms a part of the circuit and the exposed metal parts are energized, thereby creating the danger of shock to personnel touching them.

The above equipment must have the safety officer's approval and must satisfy one of the following conditions to be permitted on the base:

a) The equipment has a built-in power transformer which completely isolates the primary or line side of the transformer from the secondary or equipment side. The isolation of the primary and secondary sides of the transformer must never be inferred merely from the presence of the power transformer, but must be checked by measuring the insulation resistance from each line terminal of the transformer to the chassis and exposed metal parts of the equipment. If the insulation resistance is several megohms or less, the equipment should be provided with a grounded plug and suitable cord, the grounding conductor of the cord being connected to the chassis and exposed metal parts of the equipment at one end and to the ground contact of the plug at the other end. This arrangement will ground the chassis and exposed metal parts of the equipment, but will not ground the power supply.

b) If the equipment does not have a power transformer which isolates the primary and secondary sides as described above, an isolation transformer must be installed to perform this function. A grounded plug and suitable cord should be used with the grounding conductor of the cord connected to the chassis and the power conductors of the cord connected to the primary of the isolation transformer.

The molded housing on an electric shaver is a nonconducting plastic material, and the cutting blades are isolated from any contact with the electrical components within the shaver. For this reason, 3-prong grounding plugs are not required on electric shavers. For safe use, your electric shaver should have a completely insulated housing and isolated cutting blades, and the housing and cord must be free of cracks. If there is any doubt as to whether an electric shaver complies with the above, have it checked by the electric shop. If an electric shaver falls into a washbowl of water, LET IT GO. Unplug the cord before you remove it from the water and be sure to take it to the electric shop for inspection before using it again.

Personally owned or non-Navy standard electric lights, fans, and tools could be a shock hazard because of inferior insulation, leakage currents, and flimsy structure. Periodic inspections should be made to eliminate defective appliances from the station.

Personnel are allowed to own hobby equipment if the following stipulations are met:

a) Portable, electrically operated hobby devices should be inspected and tested by the electrical crew. Equipment which passes this inspection should be tagged as safe, giving the date of inspection. This equipment should be frequently reinspected, at least once each 6 months.

b) If the hobby tool is damaged or is obviously defective, that is, if molded housings, cords, or plugs contain cracks or breaks, or if the cord insulation breaks when sharply bent, the tool must not be used until repaired and reinspected by the electrical crew.

No personal electrical equipment, such as radios, television sets, record players, wire or tape recorders, or other personal appliances as listed above, should be used without the safety officer's tag of approval. Periodic inspection should be made to enforce this vital safety regulation.

One station has been eminently successful in enforcing the above regulations by requiring the approval signature of someone in authority at the electrical shop attached to each piece of portable equipment. This signature is on a piece of colored Scotch tape. The color is then changed at required intervals. The results are obvious. Can you use this idea at your base?

OFFICE MACHINES

Sufficient attention is not always given to the dangers of low voltage electricity in offices. In general, all electrical installation in offices should be made in compliance with the rules and regulations contained in the National Electric Code. Among the more common electrical hazards found in offices are: (1) office machines, lighting fixtures, and appliances not properly grounded; (2) defective electric cords, lighting fixtures, appliances, and switches; (3) unauthorized and improperly supervised electrical connections and repairs; and (4) loose outlet plates which may result in short circuits and cause shocks through contact with them.

Before using office machines, be sure they are properly located and not in danger of falling while in use. Never clean, oil, or adjust electrical appliances when they are in operation. When cleaning appliances which are controlled by a switch on the machine, be sure the switch is turned off and the plug pulled. Protection should be provided against moving parts on addressograph, mimeograph, bookkeeping tabulating machines, and other types of power-driven machines.

Be sure that all electrical equipment is grounded. Ground wires must be connected prior to placing the machine in motion when machines are equipped with a grounded wire.

REPLACEMENT OF FUSES

Whenever practical, a circuit should be checked out before replacing a burned-out fuse. The trouble is usually indicative of a circuit fault. Since fuses are safety devices, they should be used as such. A blown fuse should be replaced by a fuse of the same rated voltage and ampere capacity. Where removable fuse links are used, only one link of the correct rating is to be used for each fuse. Insertion of metal discs or coins in the back of plug fuses or the shorting out of cartridge fuses IS STRICTLY PROHIBITED.

When it is necessary to remove a fuse, the operating switch should be opened to remove the load, and the fuse extracted with an insulated fuse puller except where, as is usually the case on switchboards, the fuses are mounted in plug type fuse holders. These fuses are removed by unscrewing the plugs.

Only fuses of 10-ampere rated capacity or less should be removed from or replaced in energized circuits and only if an emergency exists.

Fuses larger than 10-ampere rated capacity should be removed or replaced only when the circuit is completely deenergized. After the replacement, the circuit should be energized only when the cover over the fuses is closed. Neglect of this precaution has led to injuries caused by explosion of a fuse when the circuit was energized.

When removing transformer fuses, wear rubber gloves with leather overgloves. This applies also to fuses which are being replaced by means of switch sticks equipped with fuse tongs or by means of regular fuse tongs, where the circuit voltage exceeds 150 volts but is less than 5,000 volts.

LOCK CIRCUIT BREAKER HANDLES AND TAG CIRCUITS

Work should not be done on any energized circuit, switchboard, controller, or other piece of electrical equipment unless the urgency of the work, together with the vital importance of the equipment concerned, dictates its necessity.

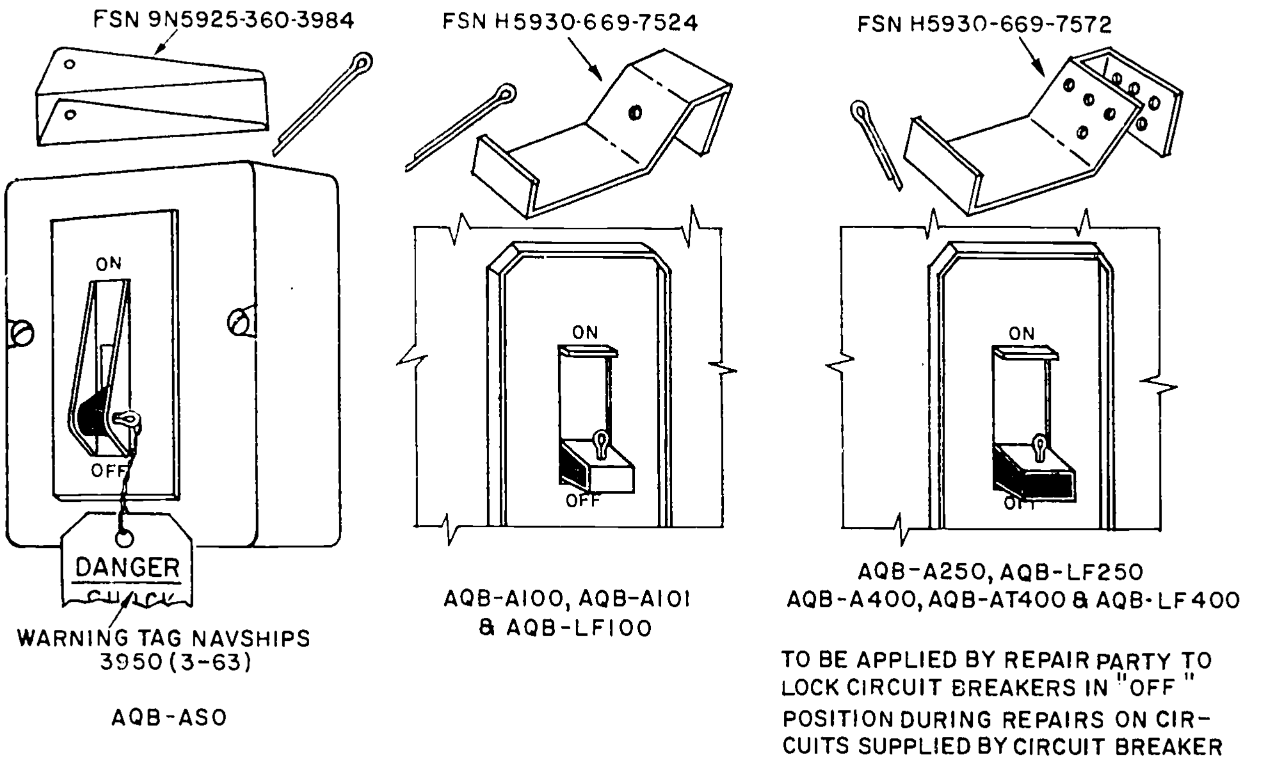

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Figure 2-8.—Handle locking devices for circuit breakers.

Circuits to be overhauled or repaired should be deenergized by opening all switches through which the power could be supplied, and the circuit should be tested with a voltmeter or voltage tester. These switches should be tagged: "DANGER SHOCK HAZARD. Do not change position of switch except by direction of

NAME. . . . . .RATE/RANK."

Warning Tag NAVSHIPS 3950 (3-63), may be used for this purpose. In case more than one repair party is engaged in repair work on an electrical circuit, a tag for each party should be placed on the supply switches. After the work has been completed, each party should remove its own tag but no other. Loads supplied from the controller in group control centers should not be worked on until the associated circuit breaker is open. If the group controller has fuses in place of a circuit breaker, the load isolation may be accomplished by removing the fuses, provided the contactor is deenergized first.

Metal locking devices are available that can be attached to the switch handles to prevent accidental operation. These locking devices can be obtained through the Ships Parts Segment of the Navy Supply System. (See fig. 2-8.)

All breaker handles are now provided with a 3/32-inch hole permitting fastening the locking device with a standard cotter pin. On earlier breakers, it may be necessary to drill a 3/32-inch hole in the handle, using the locking device as a drilling guide. The warning tags can be attached in the eye of the cotter pin.

When checking to see whether circuits are deenergized, MAKE SURE YOU CHECK METERING AND CONTROL CIRCUITS AS WELL AS POWER CIRCUITS. In many cases metering and control circuits are connected to the supply side of a circuit breaker. A check of power circuits on the load side of a circuit breaker may show that they are dead after the circuit breaker is opened, but such a check gives no assurance whatsoever that associated metering and control circuits are dead. They may or may not be, and MUST be checked to make sure.

SWITCHBOARDS

Energized switchboards are a big source of danger. No work should be undertaken on switchboards (energized or deenergized) without first obtaining the approval of the safety officer. The commanding officer's approval must also be obtained prior to the commencement of work on an energized switchboard.

Grab rods and guardrails around switchboards and other equipment should always be in position when the equipment is energized unless emergency repairs are necessary while equipment is in service. Grab rods and guardrails should be carefully maintained to ensure that they are secure and will not accidentally be dislodged. The insulating mattings provided for covering the deck in the front and rear of switchboards should always be in place.

When maintenance work is performed on a circuit, care must be exercised to ensure that the circuit remains dead and is not energized by the closing of a remote circuit breaker. All circuit breakers or switches which could energize the circuit, if closed, should be locked open by attaching a standard locking clip to the breaker handle with a cotter pin. The locked circuit breaker should then be marked with a warning tag. The lock and tag are not to be removed until the work is complete. Even though all circuit breakers to and from a switchboard are open, it is still possible for voltage to be present in the switchboard through control circuits. Switchboard system drawings should be examined to determine if voltage could be present under such circumstances. A note of the requirement for additional protective steps should be added to the standard procedures for maintaining or troubleshooting in such switchboards.

Where removable covers (plates or grilles) are provided on switchgear units, great care should be used in removal when equipment is energized. For example, unless care is exercised, a large grille cover on the rear of a switchboard section may tip in at the top or bottom after removal of some of the [illegible] or while it is being lifted off. This may [illegible] in contact with a live part, thereby causing a short circuit, an arc, or injury to personnel.

Great care should be exercised to avoid contact with any live parts of the switchboards. Many deaths have been caused by personnel in the rear of the switchboards being thrown against live bus bars or terminals. Rear-service switchboards are required to have an expanded metal enclosure with a door, enclosing all means of access to the rear of the switchboard. Battens must be kept in place. The door should be kept locked. In the case of front-service switchboards, hinged panels should not be opened except in an emergency and not until the entire switchboard is completely deenergized.

All structural parts, bases, frames, and all other metal parts of a switchboard which are not intended to operate above ground potential should be grounded. Care must be taken to remove all paint and dirt from around the mounting bolts to ensure a positive electric grounding connection. Where such inherent grounding is not provided, as in the case of some switchboards in which shock mounts are used, ground connections must be provided. If structural and other metal parts are not grounded, a breakdown of insulation may raise them to full line voltage and create a hazard.

BATTERY CHARGING

When engaged in electrolyte handling, mixing, or filling operations, personnel should wear face shields and chemically resistant gloves, footwear and aprons. To protect the eyes from burning caused by splashing, goggles should be worn. Deluge showers and eyewash fountains should be provided in the immediate vicinity of all battery maintenance and electrolyte handling operations. If an emergency occurs, quick use of these facilities may save a man's vision.

Water should NEVER be poured directly into battery acid. The acid must always be poured SLOWLY into the water to prevent excessive heating, and CAUTIOUSLY to prevent splashing. The strong acid will cause painful burns. The solution should be stirred continuously to prevent the heavier acid from flowing to the bottom of the tank without mixing.

[illegible] care to open the switch prior to removing [illegible]nnections from the batteries while they are being charged, since an inadvertent spark may cause an explosion of any escaping hydrogen. For the same reason, never smoke in this area, and be sure to provide adequate ventilation.

ENERGIZED CIRCUITS OR EQUIPMENT

Repairs are not to be made on energized circuits except in an emergency. The commanding officer or his authorized representative determines whether an emergency exists. When military considerations require that electrical repair or maintenance work be performed, but prohibit deenergizing the circuits involved, extreme measures of precaution must be used. The work should be accomplished only by adequately supervised personnel fully cognizant of the dangers involved. Every care should be taken to insulate the person performing the work from ground and to use all practical safety measures. The following precautions should be taken when applicable:

Provide ample illumination.

The person doing the work should not wear wristwatch, rings, watch chain, metal articles, or loose clothing which might make accidental contact with live parts, or which might accidentally catch and throw some part of his body into contact with live parts. Clothing and shoes should be as dry as possible.

Insulate the worker from ground by means of insulating material covering any adjacent grounded metal with which he might come in contact. Suitable insulating materials are dry wood, rubber mats, dry canvas, dry phenolic material, or even heavy dry paper in several thicknesses. Be sure that any such insulating material is dry, has no holes in it, and no conducting materials embedded in it. Cover sufficient areas so that adequate latitude is permitted for movement by the worker in doing the work.

Insofar as practical, provide insulating barriers between the work and any live metal parts immediately adjacent to the work to be done.

Use only one hand in accomplishing the work, if practical.

A rubber glove should be used on the hand not used for handling tools. If the work being done permits, rubber gloves should be worn on both hands.

Have men stationed by circuit breakers or switches, and telephone manned if necessary, so that the circuit or switchboard can be deenergized immediately in case of emergency.

A man qualified in mouth-to-mouth resuscitation and cardiac massage for electric shock should be immediately available while the work is being done.

Make sure that the connections of removable test leads on portable meters are tight. The free end of an energized test lead which comes adrift from its meter during a check of live circuits is a shock and fire hazard.

Checking the Circuit

When a circuit below 600 volts is to be checked, the voltmeter or voltage tester should first be tested on a circuit known to be operating in order to determine if the testing device is in good condition. When voltages of 600 volts or more are to be measured, the following precautions are to be observed:

(1) Deenergize the equipment to be tested.

(2) High voltage capacitors and the terminals to which the test equipment is to be connected should be discharged at least twice, with a minimum 15-second interval, by the use of a suitable insulated shorting or grounding bar.

(3) Attach a temporary, but secure, ground to the circuit.

(4) Ascertain that the test equipment controls are set correctly for testing of the high voltages.

(5) Connect to the desired test points the test leads capable of safely carrying the high voltages.

(6) Remove the temporary ground from the circuit.

(7) Withdraw from the equipment under test, making sure that you are free from the leads and in a proper position for taking meter readings correctly.

Taking the Measurements

(1) Do not use flexible leads or probes that are attached temporarily.

(2) Assign the responsibility of energizing the equipment to an assistant standing by the switch.

(3) Do not touch the test instruments while the power is on.

(4) After taking the reading, deenergize the equipment.

(5) Before removing the test leads, discharge high voltage capacitors and the terminals to which the test equipment is connected at least twice, with a minimum 15-second interval, by the use of a suitable insulated shorting or grounding bar.

(6) Attach temporary ground to the terminals to which the test instrument is connected.

(7) Remove the test leads.

(8) Remove the temporary ground.

(9) Repeat the above precautions for each measurement at applicable.

Low Voltage Work, 0 to 600 Volts

Live conductors and equipment operating at 600 volts or less may be worked upon if the following requirements are met:

(1) Adjacent live or grounded conductors and equipment should be covered with insulating material or approved rubber protective equipment.

(2) Two men should work together, particularly when work is done on energized parts carrying more than 150 volts, in wet weather, or at night. When working on energized lines, a man should not change his position on a pole without first informing others working nearby.

(3) Bare or exposed places on one conductor must be taped or covered before another conductor is exposed.

Intermediate Voltage Work,
600 to 5,000 Volts

(1) Testing Voltage Meters. All conductors and equipment must be considered as carrying current and as being alive until it has been determined beyond doubt that they are dead. When positive proof as to whether a conductor or a piece of equipment is energized cannot be established by a visual check, an approved voltage detector should be used. Before being used, the detector must be checked on a conductor that is known to be alive and a positive indication noted. This check on a known live conductor must be repeated after the test on a dead conductor has been made. When it is not possible to recheck the voltage detector on a live conductor, two voltage detectors should be used, one as a check against the other.

(2) Insulating Equipment. When work is to be done on or within reach of conductors or equipment operating between 600 and 5,000 volts, energized and grounded conductors or equipment within reach must be isolated with suitable barriers or covered with rubber hose line, insulator hoods, line protectors (pigs), or blankets. If it becomes necessary for the workman to change his working position, he must cover or barricade any energized or grounded conductors or equipment that will be within reach in the new position.

High Voltage Work,
5,000 Volts and Over

Lines and equipment operating at 5,000 volts or over must be deenergized and grounded before work is started, except in emergency repairs on overhead lines, which may be worked on alive with approved hot-line tools.

Body Clearance for High Voltage Work

A minimum body clearance from energized lines and equipment should be maintained by men working on or around electrical equipment of high voltage, as shown below:

Operating Voltage (Kilovolts)	Minimum Distance (Feet)
5 to 7.5	1
7.5 to 12	2
12 to 33	3

Remember: Never hold a line clear of a lineman on the pole. Secure it by live-line tools and lock it in a clamp.

Additional information relative to safety may be obtained from the Department of the Navy Safety Precautions for Shore Activities, NAVMAT

P-5100. Become familiar with its contents. This knowledge may save your life or the lives of some of your men.

Live-Line Barehand Work

The live-line barehand technique utilizing the insulated aerial servicing platform is prohibited unless specific approval is granted by the Naval Facilities Engineering Command.

Use and Care of Hot-Line Tools

The following precautions must be taken when hot-line tools are used:

(1) Work with hot-line tools should not be performed when rain or snow is imminent or falling, or when heavy fog, dew, or any form of excessive moisture is present.

(2) When working on lines energized at more than 5,000 volts, use approved hot-line tools WITHOUT rubber gloves. (Rubber gloves prevent detection of brush discharges.) Handle series street lighting circuits supported on arms with other lines energized at more than 5,000 volts, the same as the power supply conductors.

(3) No more than one conductor may be worked on at a time with hot-line tools.

(4) Hot-line tools must be kept dry and free from dirt. Tools which have been subjected to damp weather must be thoroughly dried and tested before being used again. They must never be placed on the ground.

(5) Hot-line tools being transported on line trucks should be stored so as to prevent damage to them. Waterproof canvas bags may be used for this purpose. A compartment equipped with padded hooks or bands may be built into the truck for this purpose.

Periodic treatment of hot-line tools in a drying cabinet for 48 hours to 1 week per month at 90 to 100 degrees Fahrenheit is recommended under average conditions. Hot-line sticks must be tested with 75,000 volts per foot for 5 minutes. If they break down, they must be returned to the drying room.

WORLD'S BEST PROTECTIVE DEVICE

In setting forth these rules and regulations for safe practices, it is fully recognized that all possible hazardous conditions cannot be foreseen and covered by adequate precautionary measures. Mental alertness and effective procedures in handling equipment and performing work are required at all times by all men so that hazards may be detected and overcome before they lead to personnel injury, or damage to equipment.

Remember

THE WORLD'S BEST
PROTECTIVE DEVICE
IS A CAREFUL INDIVIDUAL

FIGHTING FIRES

It is extremely important that all personnel know and understand all there is to know about fire prevention and firefighting. Part of the knowledge is to know the type and location of all firefighting equipment and apparatus in the immediate working and living spaces, and throughout the area. It is too late to get this knowledge after a fire has started; the time is now. Remember—If there is a special phone number on your base to call in case of fire, require all the men to memorize it. The time lost looking for this emergency number may put the fire beyond control.

RULES TO FOLLOW

In case of an electrical fire proceed as follows:

1. Deenergize the circuit or equipment affected and shift the load to standby circuits or equipment. In case no standby circuit or equipment is available, deenergize the circuit or equipment affected by the fire, except in extreme emergency when the need for uninterrupted power outweighs the risk incurred by leaving it energized.

2. Report the fire.

3. Secure ventilation by closing air vents or windows.

4. Attack the fire with portable CO_2 extinguishers (or a CO_2 hose reel system, if available) as follows:

a. Remove the locking pin from the release valve.

b. Grasp the horn handle by the insulated (thermal) grip; the grip is insulated against possible hand frostbite.

c. Squeeze the release lever (or turn the wheel) to open the valve and thus release the carbon dioxide; at the same time, direct the discharge flow of the carbon dioxide toward the base of the fire.

d. Aim and move the horn of the extinguisher slowly from side to side.

e. Do not stop the discharge from the extinguisher too soon. When the fire has been extinguished, coat the critical surface areas involved with carbon dioxide "snow" in order to cool the substances (fuels) involved and prevent a rekindling of the fire.

Care must be taken to avoid high concentrations of carbon dioxide in confined spaces, as there is danger of suffocation to personnel unless special apparatus is available. In electrical fires, remember that quick action is most needed for deenergizing the circuit. When this has been done, stop, look, and think, and then act fast to extinguish the fire before it spreads.

Carbon dioxide is the preferred fire extinguisher for use on electrical fires. It is a noncorrosive gas which does not damage cables or equipment. It is nonconducting, and the stream of carbon dioxide from an extinguisher can be directed against energized circuits without danger of shock.

Extreme care must be used if freshwater or saltwater or foam is directed at an energized circuit, since all of these can conduct current and shock firefighters. In addition, equipment damaged by saltwater or foam is more difficult to recondition than if carbon dioxide had been used. Consequently, while water or foam may have to be used to prevent a disastrous fire, it is decidedly advantageous and preferable to use carbon dioxide alone.

In cases of cable fires, in which the inner layers of insulation or insulation covered by armor are burning, the only positive method of preventing the fire from running the length of the cable is to cut the cable. Use an ax with a wooden handle, taking care to protect your eyes from any flash when the wires are severed, and separate the two ends.

Don't forget to request the replacement or recharge of fire extinguishers immediately after they have been discharged. Never turn on current in a building in which a fire has occurred, if electric wiring has been affected. A careful inspection should be made, because parts damaged by heat, water, or foam may become short circuited and restart the fire.

PREVENTING FIRES

General cleanliness of the work area and of electrical apparatus is essential for the prevention of fires. Oil, grease, and carbon dust can be ignited by electrical arcing. Therefore, electrical equipment should be kept absolutely clean and free of all such deposits.

Wiping rags and other flammable waste material must always be placed in tightly closed metal containers, which must be emptied at the end of the day's work.

Containers holding paints, varnishes, cleaners, or any volatile solvents should be kept tightly closed when not in actual use. They must be stored in a separate building or in a fire-resisting room which is well-ventilated and where they will not be exposed to excessive heat or to the direct rays of the sun.

Alcohol should never be used for cleaning electrical equipment since it not only constitutes a fire hazard, but it also results in damage to many kinds of insulation. When cleaning electrical equipment or parts, always use an approved cleaning agent such as FSN W 6850-274-5421. It is a dry cleaning solvent, Type II, covered by the latest issue of Specification D-680.

SAFETY EDUCATION

Many supervisors feel that it is only necessary to provide safeguards, after which safety will take care of itself. Provision of safeguards is a move in the right direction, but it alone will not get good results. To maintain a good safety record, you, as the supervisor, need to employ a combination of safety devices and safety training. If each man has had sound safety training, he will be able to guard against hazards for which safety devices are impracticable. You must, however, train every man in the use of safeguards, explaining why, as well as how, they should be used. How many times have you seen a man shut off the power to a motor-driven machine and then walk away from it before it has stopped turning? This man knew how, but not why. By providing the necessary training, the alert supervisor makes sure his men are not careless with safeguards.

Standup safety meetings should be held in the shop once every week. The meetings should be held at or near the work area. Instead of a routine safety lecture, it is better to hold a group discussion on specific accidents that are to be guarded against or that have happened in the unit. The men should be encouraged to express their ideas. Your group should reach a conclusion as to how specific accidents can be prevented.

Another type of safety meeting is one in which the supervisor presents a safety problem that has developed because of new work or new equipment. Again, the men should be invited to express their ideas.

In a third type of safety meeting, actual demonstrations and practice by the group are carried out. You demonstrate how to lift, for example, and then have the men practice lifting.

If the subject of your safety meeting is the safe use of a portable grinder, bring a portable grinder to the meeting and show how to use it—do not just talk about how to use it. Again, let the men practice after they have been shown how.

Make these meetings interesting; it takes a lot of ingenuity to keep them from becoming dull. Consider having the men themselves rotate as leaders of the safety meetings—an excellent device to maintain interest. Hundreds of good motion pictures and other visual aids are available on safety subjects. Use them! But select subject mater that is timely and fitting. Never complain or scold at these meetings. Also, make sure to set a time limit for each meeting, and avoid exceeding it.

ACCIDENT REPORTING

When an accident occurs in your shop, office, or within your crew, you must fill out an OPNAV Form 5100/1, Accidental Injury/Death Report (figs. 2-9 through 2-12). This form provides a method of recording the essential facts concerning an accident, from which data for use in accident prevention can be compiled. Item 27—"Corrective action taken/recommended"—is the most important part of this report. Your response to this item provides a clue to your attitude toward safety. Too many supervisors respond with, "The man was warned to be more careful." Such a response is useless since it does not tie in with the rest of the report. If an unsafe working condition is the cause of the accident, you cannot correct it by warning the man to be more careful. Study the report; analyze it; then take corrective action. When properly used, this report is one of your best accident prevention tools. In many cases, the difference between a minor accident and a major one is a matter of luck. Do not ignore accidents that result in small cuts and bruises; investigate the reasons for them and correct the causes. If you do this, you will have a safe and efficient shop or office.

ACCIDENT INVESTIGATION

To fill out OPNAV Form 5100/1 properly, as shown in figures 2-9 and 2-10, you must conduct an accident investigation to get answers to questions such as those in the six categories below.

1. UNSAFE CONDITIONS. Was the equipment improperly guarded? Was the equipment or material rough, slippery, sharp-edged, decayed, worn, or cracked? Was there a hazardous arrangement, such as congested work space, lack of proper lifting equipment, or unsafe planning? Was there proper illumination or ventilation? Was the man dressed properly for the job? Was the man provided with proper respirator, goggles, gloves, etc?

2. TYPE OF ACCIDENT. Was the man struck by an object? Did the man fall at the same level or to a different level? Was he caught in or between objects? Did he slip (not fall) or overexert himself?

3. UNSAFE ACT. Was the man operating a machine without proper authorization? Was he

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: NAVAL CONSTRUCTION BATTALION CENTER PORT HUENEME, CALIFORNIA 93041

2A. COMMAND AUTHORITY EXERCISED BY: CONSTRUCTION CENTER

2B. GCM AUTHORITY EXERCISED BY:

3. REPORT NUMBER: 5

4. NAME OF PERSON INJURED/KILLED (FIRST, MIDDLE, LAST): ANDERSON, John P.

5A. SERVICE/BADGE NO.: B4823456

5B. SOCIAL SECURITY NO.: 247-83-2248

6. RANK & DESIGNATOR RATE AND NEC/CIVILIAN OCCUPATION: CM2, USN

7. SEX: M

8. AGE: 24

9A. TIME IN SERVICE (MIL ONLY): 6 Years

9B. YEARS EXPERIENCE (CIV ONLY)

10A. MIL: [X] USN [ ] USMR [ ] OTHER

10B. CIV: [ ] EMPLOYEE [ ] DEPENDENT [ ] OTHER

11A. DUTY STATUS MIL: [ ] EX ACT DU [X] 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
0950	19	Apr.	19-	Thursday

13. PLACE OF OCCURRENCE: [ ] ABOARD SHIP [X] ASHORE — DESCRIBE LOCATION: Automotive Shop

14. DAYS LOST/CHARGED: (0)

15. WEATHER/NATURAL DISASTER: NA

16. LIGHT CONDITIONS AT SITE: Good

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.)

Petty Officer ANDERSON was standing on the front bumper of a 5-ton truck leaning over the radiator grill to inspect the radiator hoses and fan belts when his feet slipped off the wet bumper, causing him to fall on the upper section of the radiator grill.

WITNESSES: NAME, RANK/RATE, ADDRESS
None

18. KIND OF INJURY: Abrasion

19. BODY PART INJURED: Chest

20. SOURCE OF INJURY (OBJECT, SUBSTANCE, ETC. WHICH CONTACTED THE BODY AND INJURED PERSON): Vehicle--Radiator Grill

21. KIND OF ACCIDENT (FALL, CRUSHED, STRUCK BY, ETC.): Striking Against

22. HAZARDOUS CONDITION (WHAT CONDITION CAUSED, PERMITTED, CONTRIBUTED TO ACCIDENT WHICH RESULTED IN INJURY): Wet Bumper [ ] NOT APPLICABLE

23. AGENCY (AND AGENCY PART) OF ACCIDENT (OBJECT, SUBSTANCE, ETC. TO WHICH THE HAZARDOUS CONDITION APPLIED): U.S. Navy [ ] NOT APPLICABLE

24. UNSAFE ACT (WHAT PERSONAL ACTION CAUSED OR ALLOWED ACCIDENT TO OCCUR): [X] BY INJURED MAN [ ] BY ANOTHER [ ] NOT APPLICABLE

25. UNSAFE PERSONAL FACTOR (MENTAL OR PHYSICAL CONDITION WHICH RESULTED IN OR CONTRIBUTED TO THE UNSAFE ACT): Failure to use step stands

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

29.52.1

Figure 2-9.—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?):

Instructed Petty Officer ANDERSON in the use of the step stands with non-skid treads which are provided by the shop for this type work.

28. SIGNATURE OF PERSON PREPARING REPORT	29. TITLE AND GRADE	30. DATE
Jim Nelson (signature) Jim Nelson	CMCS, USN	19 Apr. 19-

31. REVIEW AND COMMENTS OF SAFETY OFFICER OR COMMANDING OFFICER

32.	33. TITLE AND GRADE	34. DATE

ADDITIONAL INFORMATION WHEN REQUIRED BY JAG

35. CONDITION OF INDIVIDUAL AT TIME OF THIS OCCURRENCE:
WITH 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	DATE	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)

29.52.2

Figure 2-10.—Accidental Injury/Death Report, OPNAV Form 5100/1 (back).

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

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

INSTRUCTIONS FOR ACCIDENTAL INJURY DEATH REPORT

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 [illegible] COMSERVLANT [illegible] in the case of NAVSTA NORVA, COMNAVSHIPSYSCOM in the case of a ship yard, etc.

Block 2B. OEM 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. (i.e. 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 ommission 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 35-50. 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).

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Figure 2-11.—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 IMPROPERLY 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

D-19990

43

29.52.4

Figure 2-12.—Instructions for Accidental Injury/Death Report (back).

working at an unsafe speed, that is, too fast or too slow? Was a safety device made inoperative, that is, blocked out or removed? Was a load made unsafe, or were tools or equipment put in an unsafe place where they would fall? Did someone fail to wipe oil, water, grease, paint, or some other substance from working surfaces? Did the injured man take an unsafe position or posture? Did he lift with a bent back or while in an awkward position? Did he lift jerkily? Was he using improper means of ascending or descending? Was the injury caused by failure to wear the provided safe attire or personal protective devices, such as goggles, gloves, masks, aprons, or safety shoes?

4. UNSAFE PERSONAL FACTOR. Was the man absentminded or inattentive? Did he fail to understand instructions, regulations, or safety rules? Did he willfully disregard instructions or safety rules? Was he unaware of safe practices, unpracticed, or unskilled? Was he unable to recognize or appreciate the hazards? Did he have a bodily defect, such as poor eyesight, defective hearing, or hernia?

5. TYPE OF INJURY. Did he sustain a cut, bruise, sprain, strain, hernia, or fracture?

6. PART OF BODY AFFECTED. Did the injury involve an arm, leg, ribs, feet, fingers, head, or other part of the body?

These categories suggest some of the things (not all) a supervisor must investigate and report when accidents occur. Remember there are some questions in these categories that request medical information which can only be obtained from a doctor. Each accident is different, and each should be investigated and judged individually. Do not jump to conclusions. Start each investigation with an open mind. The most important reason for any accident investigation is prevention of a similar accident.

FIRST AID

First aid is the immediate and temporary care given the victim of an accident before treatment can be administered by trained medical personnel. Your work may frequently be performed in areas where medical personnel are not readily available. It is important, therefore, for you and other CE's to be well trained in first aid procedures.

GENERAL

Place the victim in a prone position (lying flat), with his head level with the body until treatment requires movement. Check for hemorrhage, stoppage of breathing, wounds, fractures, dislocations, and other injuries. If clothing must be removed, cut it away—do not move the injured person. Do not permit the victim to see his injury and keep onlookers away from the scene.

Provide IMMEDIATE treatment for serious bleeding, stoppage of breathing, and poisoning—in that order. Keep the victim warm and treat for shock. Call a medical officer and give the following information: (1) the location of the victim; (2) the nature, cause, and probable extent of the injury; (3) available supplies; and (4) the type of first aid being given.

Unless it is absolutely necessary, to avoid complicating the injury do not hurry while moving the injured person—and KEEP CALM.

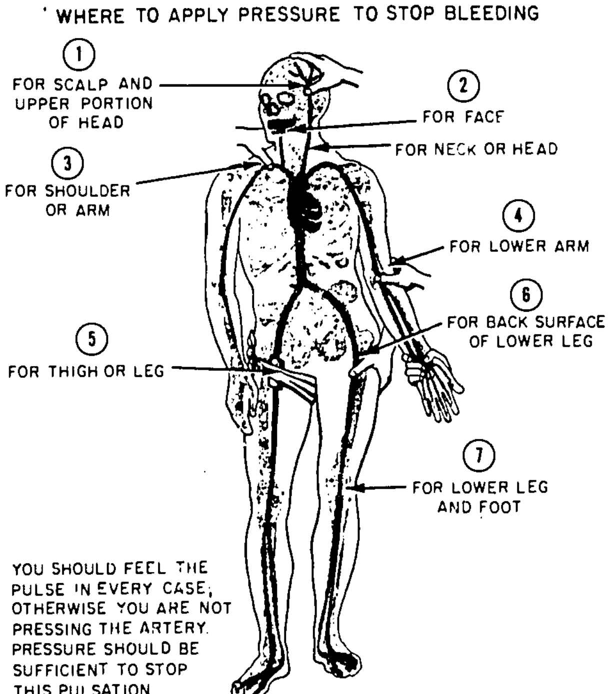
Bleeding

A break in the skin may be subject to two primary dangers: serious bleeding and/or infection. When the bleeding is severe, stop it as rapidly as possible by applying a thick layer of gauze or clean folded handkerchiefs against the bleeding point and applying firm pressure with your hand. Elevate the injured part if possible.

If the bleeding is not controlled in this manner, apply hand pressure at a pressure point.

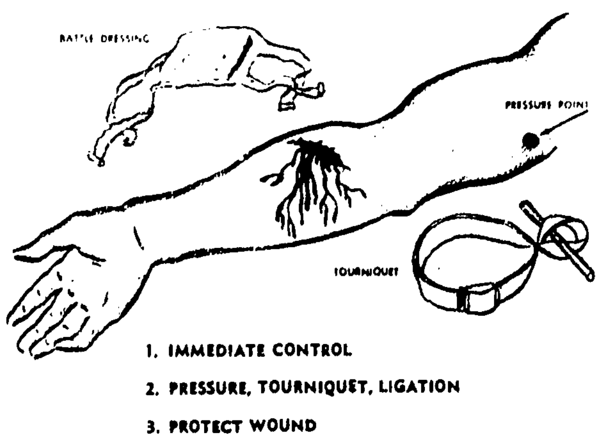
A PRESSURE POINT is a point between the heart and the wound where pressure may be applied to the artery to close off the blood supply to the wounded part. The main pressure points are shown in figure 2-13.

If a pressure dressing or hand pressure does not control the hemorrhage, a tourniquet (fig. 2-14) may be used. The tourniquet should be placed above the wound and as near it as possible. (Tourniquets are used only on extremities.) To be effective, the tourniquet must



136.3(73G)

Figure 2-13.—Seven pressure points to stop arterial bleeding.



136.2:4

Figure 2-14.—Measures for control of arterial hemorrhage.

be tightened until the arterial flow stops, but no tighter. Excessive pressure will cause damage to the tissue beneath it. However, if the tourniquet is not applied tightly enough and only stops the venous flow, it may actually increase the loss of arterial blood.

The tourniquet should never be covered, and the time it was applied must be noted on the casualty tag or on a tag attached to the tourniquet. A properly applied tourniquet can be retained safely for 2 or 3 hours without being loosened. In cold weather it can be left on even longer. It is best, especially among those with limited experience and knowledge in the treatment of shock and hemorrhage, to leave the tourniquet on until the hemorrhage can be controlled by other means. A TOURNIQUET SHOULD NOT BE USED UNLESS THE HEMORRHAGE CANNOT BE CONTROLLED BY ANY OTHER MEANS. After the bleeding is controlled, treat the victim for shock.

Shock Symptoms and Treatment

Every injured person is potentially in shock, since shock usually occurs whenever there is severe injury of any part of the body. Start treatment for shock immediately; do not wait for symptoms to develop. Some symptoms are shown in figure 2-15.

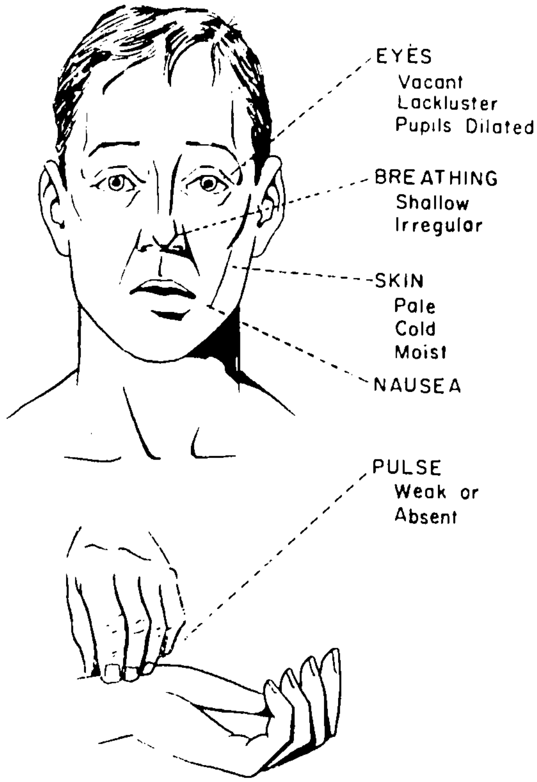
In treating a victim for shock, try to retain the victim's body heat. Place blankets or clothing underneath as well as on top of the victim (fig. 2-16). Remove cold or wet clothing avoiding unnecessary exposure, and keep the victim's head lower than his feet unless he has a head or chest injury. If he is conscious, provide him with small doses of hot coffee or tea if available, and he is not nauseated or vomiting. Remember—shock is easier to prevent than to cure.

EMERGENCY PROCEDURES

Resuscitation is a general term which covers all of the measures taken to restore life or consciousness to one apparently dead. These measures include ARTIFICIAL RESPIRATION to restore normal respiratory functions and CLOSED CHEST CARDIAC MASSAGE to restore normal heart beat.

Artificial Respiration

Begin artificial respiration IMMEDIATELY. Seconds, rather than minutes, count. The person nearest the victim should start the resuscitation without delay and call or send others for assistance and medical aid. The only logical permissible delay is that required to free the man from his contact with electricity in the quickest safest way. This step, while it must



136.5
Figure 2-15.—Look for these symptoms in shock.

be taken quickly, must be done with great care; otherwise, there might be two victims instead of one.

> WARNING
>
> DO NOT attempt to administer first aid or come into physical contact with an electric shock victim before the voltage is cut off, or if the voltage cannot be turned off immediately, before the victim has been removed from the live conductor.

To aid a victim of electric shock after removing him from contact with electricity, immediately apply mouth-to-mouth or mouth-to-nose artificial respiration (figs. 2-17 and 2-18), or both if it is a child or a person with

136.6
Figure 2-16.—Patient in position for treatment of shock.

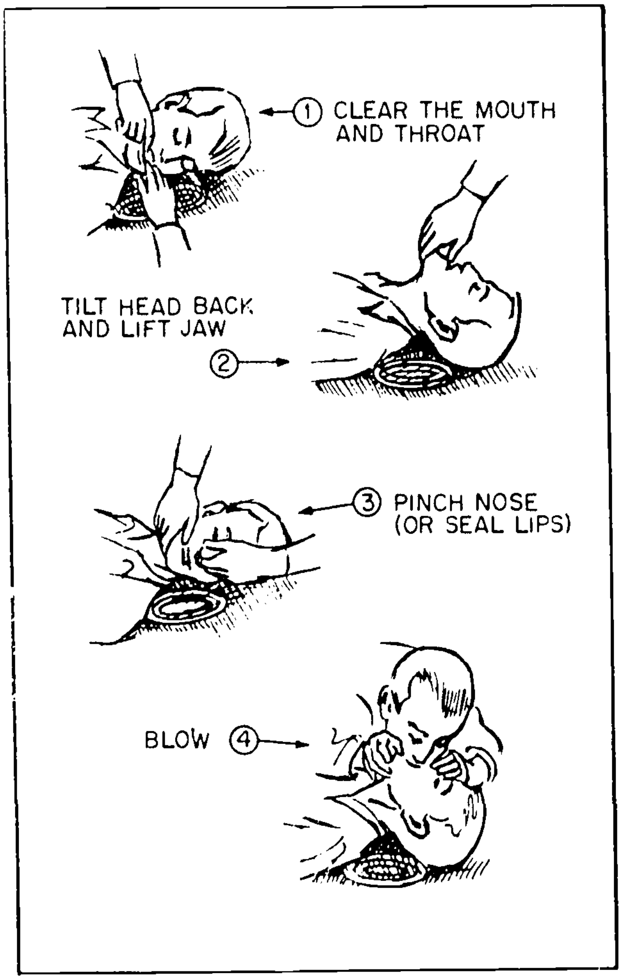
ARTIFICIAL RESPIRATION

MOUTH-TO-MOUTH OR MOUTH-TO-NOSE RESCUE BREATHING

1. PLACE CASUALTY ON BACK IMMEDIATELY
DON'T WASTE TIME MOVING TO A BETTER PLACE, LOOSENING CLOTHING, OR DRAINING WATER FROM LUNGS.
2. QUICKLY CLEAR MOUTH AND THROAT
REMOVE MUCUS, FOOD, DENTURES, CHEWING GUM, AND OTHER OBSTRUCTIONS.
3. TILT HEAD BACK AS FAR AS POSSIBLE
THE HEAD SHOULD BE IN A "CHIN-UP" OR "SNIFF" POSITION AND THE NECK STRETCHED.
4. LIFT LOWER JAW FORWARD
GRASP JAW BY PLACING THUMB INTO CORNER OF MOUTH. DO NOT HOLD OR DEPRESS TONGUE.
5. PINCH NOSE SHUT OR SEAL MOUTH
PREVENT AIR LEAKAGE.
6. OPEN YOUR MOUTH WIDE AND BLOW
TAKE A DEEP BREATH AND BLOW FORCEFULLY (EXCEPT FOR BABIES) INTO MOUTH OR NOSE UNTIL YOU SEE CHEST RISE.
7. LISTEN FOR EXHALATION
QUICKLY REMOVE YOUR MOUTH WHEN CHEST RISES. LIFT JAW HIGHER IF VICTIM MAKES SNORING OR GURGLING SOUNDS.
8. REPEAT STEPS SIX AND SEVEN 12 TO 20 TIMES PER MINUTE
CONTINUE UNTIL VICTIM BEGINS TO BREATHE NORMALLY.

* FOR INFANTS SEAL BOTH MOUTH AND NOSE WITH YOUR MOUTH
BLOW WITH SMALL PUFFS OF AIR FROM YOUR CHEEKS.

4.224
Figure 2-17.—Procedure for artificial respiration.



4.224
Figure 2-18.—Mouth-to-mouth respiration.

a small face. If there is no pulse, immediately apply heart massage also (fig. 2-19).

Don't waste precious seconds carrying the victim from cramped, wet, or isolated locations or to loosen his clothing. Revival chances decrease rapidly if not started within 3 minutes after shock.

To eliminate physical contact from mouth-to-mouth artificial respiration, an oropharyngeal airway may be used if available; if not, a cloth or handkerchief may be placed over the victim's face. If assistance is available, take turns breathing into the victim and massaging his heart.

External Cardiac Massage

If the victim has suffered an electric shock and has no heart beat, he has had a cardiac arrest. This is demonstrated by complete absence of any pulse at the wrist or the neck, dilated pupils, and weak or stopped respiration. The victim may appear to be dead.

The object of closed chest cardiac massage is to squeeze the heart through the chest wall, thereby emptying it to create a peripheral pulse. This must be done about 60 times each minute.

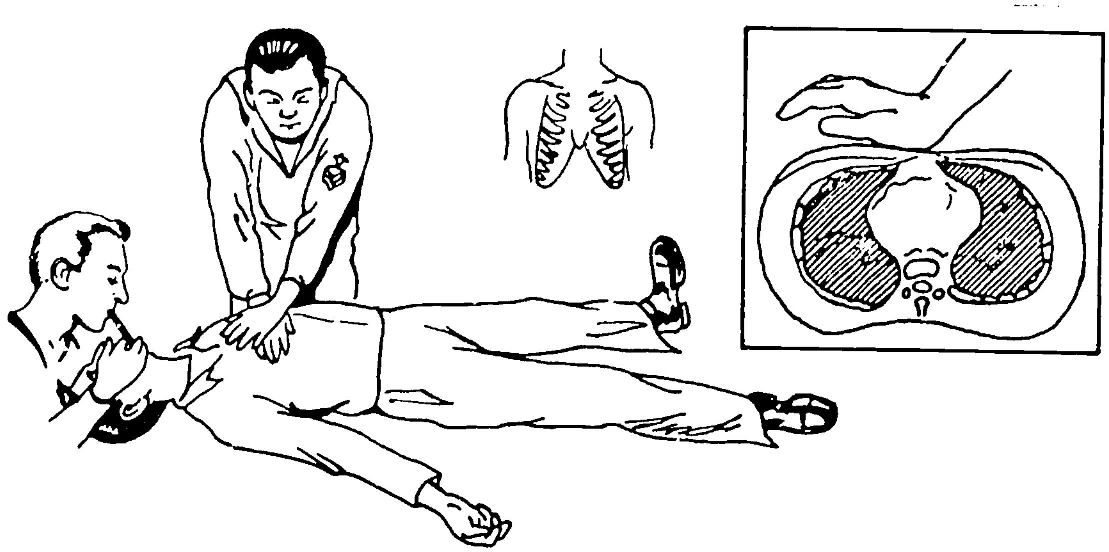
DIRECTIONS.—Place the victim on his back on the floor or other firm surface. Expose his chest. Kneel beside victim; feel for lower end of his breastbone; place one hand across the breastbone so the heel of your hand covers the lower part; place your other hand on top of the first so that the fingers point toward the victim's neck (fig. 2-19).

With arms nearly straight, rock forward so that a controlled amount of your body weight is transmitted through your arms and hands to the breastbone. The amount of pressure to apply will vary with the victim. It should be applied as smoothly as possible. With an adult, the chest wall should be depressed 2 to 3 inches for the first pressure application and 1 to 1-1/2 inches for each additional pressure application.

Repeat application of pressure about 60 to 80 times per minute. An assistant should be ventilating the victim's lungs preferably with pure oxygen under intermittent positive pressure; otherwise with mouth-to-mouth resuscitation. However, closed chest massage will cause some ventilation of the lungs. Therefore, if you are alone, you must concentrate on the massage until help arrives.

Direct other assistants, when available, to keep checking victim's pulse. Use the least pressure [illegible] will secure an effective pulse beat. The pupils will become smaller when effective cardiac massage is being performed. Pause occasionally to determine if a spontaneous heart beat has returned.

PRECAUTIONS.—Make every effort to keep the hands positioned as described in order to prevent injuries to the liver, ribs, or other vital organs. Since the heart cannot recover unless supplied with oxygenated blood, it is



4.224

Figure 2-19.—Cardiac massage.

necessary to accompany cardiac massage with mouth-to-mouth or mouth-to-nose artificial respiration. When there is only one operator, the cardiac massage must be interrupted every half minute or so to institute rapid mouth-to-mouth breathing for three or four respirations.

BURNS

The principal dangers from burns are shock and infection. All casualty care measures must be directed toward combating shock, relieving the casualty's pain, and preventing infection.

Classification of Burns

Burns are classified in two ways; their causes and the depth of skin damage.

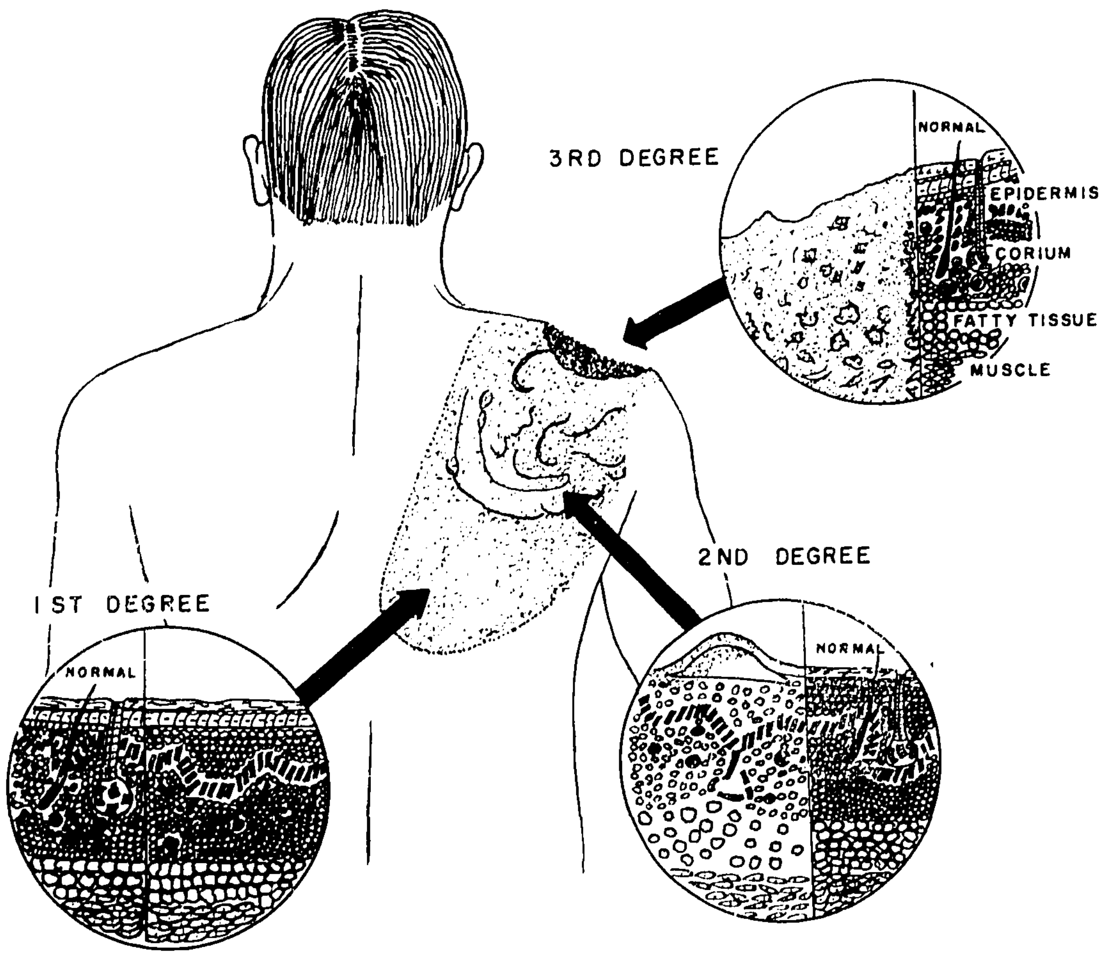
Thermal burns are the direct result of heat, such as fire, scalding, sun or explosion blast. Chemical burns are produced by chemical action such as battery acid on tissues. Electrical burns may be caused by electrical current passing through tissues or a superficial wound caused by electrical flash.

Burns may be classified as first, second, or third degree, based on the depth of skin damage (fig. 2-20). First-degree burns are characterized only by reddening of the skin. Second-degree burns are characterized by blistering of the skin, either early or late. They are the most painful type of burn. The complete thickness of the skin is not destroyed. Third-degree burns are characterized by complete destruction of the skin with charring and cooking of the deeper tissues. This is the most serious type of burn, for it produces a deeper state of shock and more permanent damage and disfigurement. It is not as painful as a second-degree burn because the sensory nerve endings have been destroyed.

Emergency Treatment

The degree of the burn, as well as the skin area involved, determines the procedures used in treatment of burns. Involvement of large skin areas requires a different approach than small areas. To estimate the amount of skin area affected, use fig. 2-21.

As a guideline, consider that a burn of more than 20 percent of the body surface endangers life. The old or the very young victim does not tolerate burn injuries well. Without adequate treatment, a burn of more than 30 percent of the body surface is usually fatal to adults.



136.32

Figure 2-20.—Types and degrees of burns.

If time and facilities permit caring for superficial burns, the area should be cleaned with soap and water. A simple sterile dressing of fine-mesh, dry gauze is then applied over the area to protect it from infection and mechanical trauma.

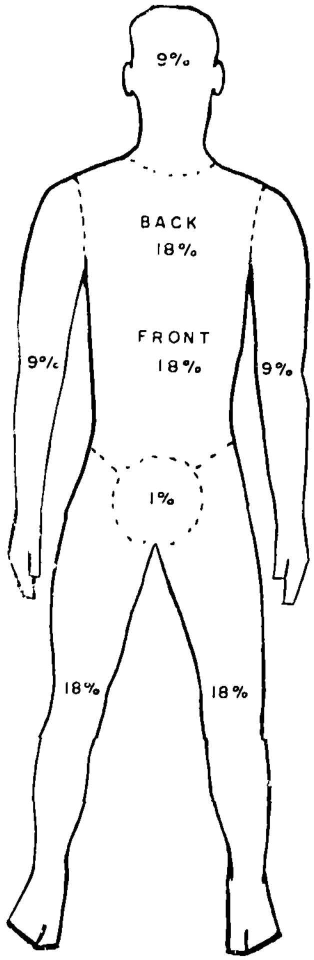
Based on field level casualty treatment conditions, superficial burns include first-degree burns and lesser second-degree burns, which need little attention beyond self-care. Treatment of the more serious second-degree burns and third-degree burns is the subject of the following discussion.

When emergency treatment of deep burn casualties is required, treat the victim for shock first. Make him as comfortable as possible, and protect him from cold, excessive heat, and rough handling.

The loss of body fluids is the main factor in burn shock. Start oral therapy gradually at first by giving him small amounts of hot coffee or tea frequently. These drinks, or fruit juice or sugar water, must be given only if the victim is conscious, able to swallow, and has no internal injuries.

Pain is closely allied to the degree of shock, and should be relieved as soon as possible.

To enable personnel trained in the management of burns to determine the type of treatment, no medication should be applied to burns during emergency treatment.



136.31
Figure 2-21.—Computing body surface.

After the victim has been treated for pain and shock, a compress and bandage may be applied to protect the burned area. If a Universal protective dressing is not available, fine-mesh gauze may be substituted. Constricting articles of clothing and ornaments should be cut away or removed, and the burned area should be elevated and immobilized.

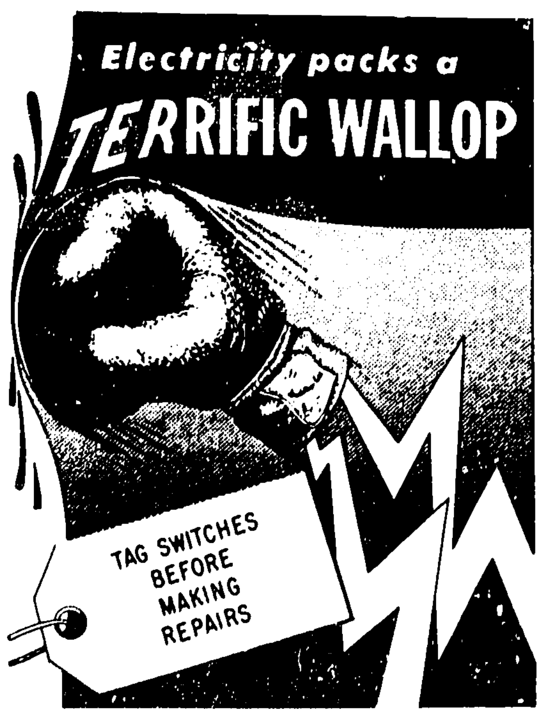
Victims with extensive deep burns must be evacuated to a medical facility for treatment as rapidly as possible. Pain should be alleviated and shock must be controlled before and during evacuation.

Debris and loose clothing must be removed from burned areas to prevent irritation while the victim is being treated and transported. Clothing that sticks to the burn may be cut around the burn and the adhering cloth allowed to remain until it can be removed at the medical facility. The area of the burn is usually sterile; therefore, care should be taken not to contaminate it.

Remember—in electric shock, the burn may have to be temporarily ignored while resuscitative measures are carried out. Treatment for chemical burns varies depending upon the agent that caused the burns. Flooding the affected area caused by the burn with large amounts of preferably clean, fresh, cool water will minimize damage provided that not too much force is used upon application. Ice water treatment is an effective pain reducer, if available.

Become familiar with the STANDARD FIRST AID TRAINING COURSE, NAVPERS 10081-B. Your prompt and correct response to an emergency may save a life.

Above all, remember your A B C's: Always Be Careful. (See fig. 2-22.)



40.67
Figure 2-22.—Safety.

CHAPTER 3

BLUEPRINTS, DIAGRAMS AND SCHEMATICS

Diagrams and schematics are maps which indicate the location of circuits and circuit connections of electrical installations and equipment. When properly utilized, they are an invaluable aid in troubleshooting or in determining faults in an electrical circuit. Locating and repairing faults are some of the most important work assignments you will have. You will also be required to install new circuits or repair old construction.

Blueprints are reproductions of the working drawings of schematics. The proper use of blueprints pays dividends in many ways. For example, blueprints will save many man-hours of "sight-traveling" cables as you seek malfunctions or an unknown termination point.

The ships, planes, buildings, and guns of the Navy were built from plans on blueprints and they are operated, checked, and maintained according to information found on those blueprints. When mechanisms fail in service or are damaged in battle, blueprints are used to aid the repairman. When new parts are to be made or the system is expanded, blueprints provide the necessary information. Remember, too, that much planning and manpower and material estimating are based on the information contained in these blueprints. This chapter discusses the function and care of blueprints, and the importance of being able to read and work from them.

BLUEPRINT READING

The term "blueprint reading" refers to the ability to express the meanings conveyed in drawings, whether the drawings are actually blueprints or not. Be aware that all blueprints are not blue in color, but a drawing of any color which delineates a master or key plan. An important reference is the basic Navy training manual Blueprint Reading and Sketching, NAVEDTRA 10077-C. If necessary, review chapters 1 through 5 of NAVEDTRA 10077-C; these chapters provide information that will aid the CE in duties involving blueprint reading.

CARE OF BLUEPRINTS

Blueprints are valuable permanent records which can be used again and again if you take care of them. Here are a few pointers on the care of prints:

1. Keep them out of sunlight to prevent fading.

2. DO NOT make pencil or crayon notations on a print without proper authority. If you should be instructed to mark a blueprint, use a crayon or pencil with appropriately colored lead. A yellow crayon provides good contrast to a blue background while ordinary black lead pencil marks are hard to see.

3. Avoid getting the prints wet or grease-smudged.

4. Keep prints stored properly so they can be located quickly the next time you need them. A standardized, accurate system of filing blueprints is necessary. This system ensures that the identifying marks appear in the same place, preferably at the top, when the prints are in vertical filing order.

FOLDING BLUEPRINTS

Most of the prints you see will already be folded properly. Your only concern will be to see that they are refolded correctly after being used. If you use prints that have not been folded at all, or that have been folded improperly, fold them in such a manner that the drawing number in the right-hand corner of the title block appears on the outside. (Some older drawings may have the drawing numbers placed in other portions of the title block.)

The method of folding prints depends upon the type and size of the filing cabinet, and the location of the identifying marks on the prints. It is preferable to place identifying marks at the top of prints when filing them vertically (upright), and at the bottom right-hand corner, when filing them flat. In some cases construction prints are stored in rolls.

PARTS OF A PRINT

The chief part of a drawing is, of course, the graphic representation of the object, whatever it may be, together with dimension lines, dimensions, symbols, and other graphic devices which explain the representation. Additional information is inscribed in the title block, the bill of materials, the scale, and the legends and notes.

Title Block

The title block (fig. 3-1) 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, and the date approved.

Drawing Number

The drawing number is especially important, both for purposes of filing the blueprint, and for locating the correct drawing when it is specified on another blueprint. For example, where a number of separate buildings shown on a series of blueprints are to have identical wiring systems, cross-referencing the other drawings to one plan which shows all the details saves the labor of repeating the wiring system on every drawing.

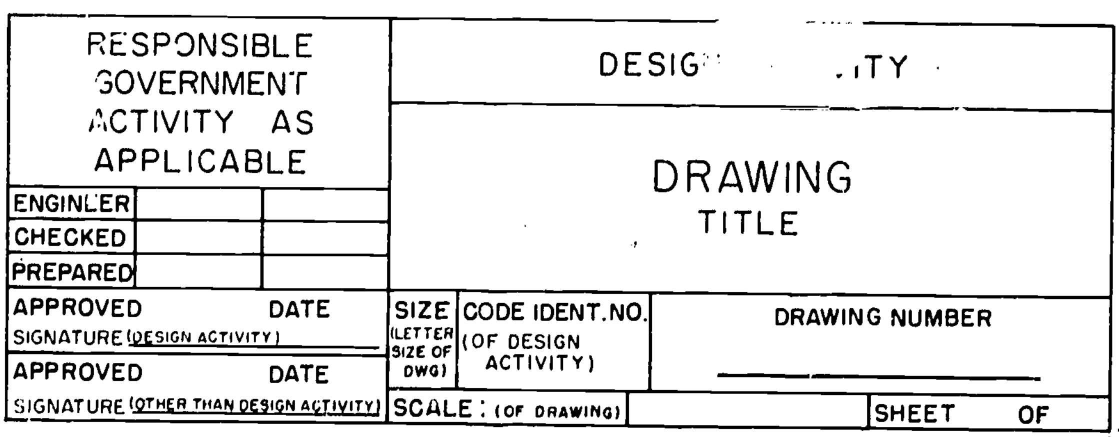
Bill of Material

The bill of material is a list of all the items required to install a particular piece of equipment or to erect a particular building. The list includes stock number, description, and quantity of each item. As you can see by referring to figure 3-2, the list is complete down to the last screw.

When equipment assemblies are received at an advanced base, it is possible for you, by checking the bill of material, to quickly determine if the items shipped are what you need for the job in hand, and whether or not they allow for changes made necessary by local conditions.

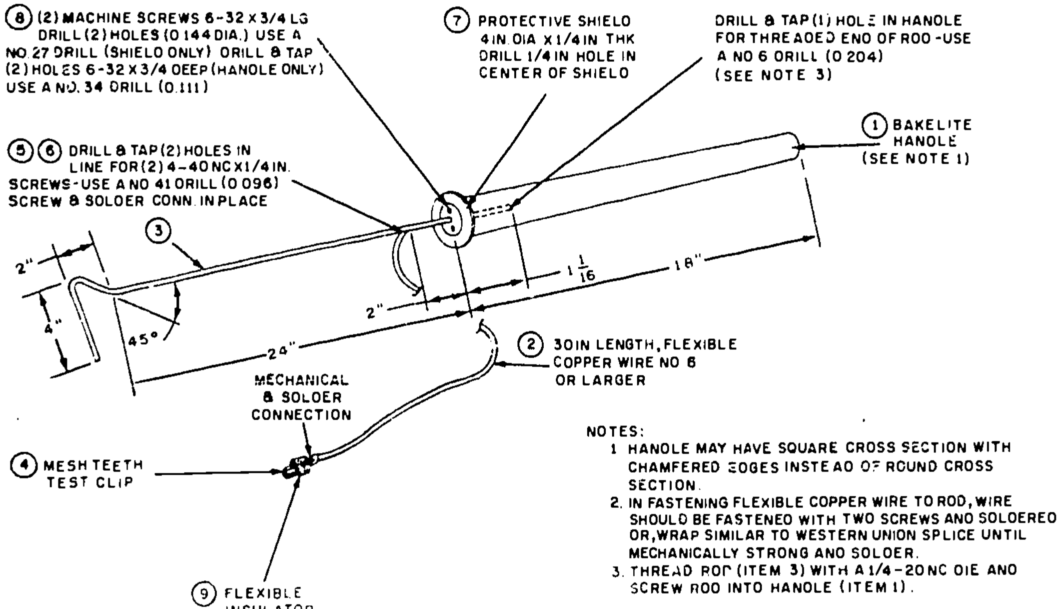
Scale

The scale of a drawing is particularly important to the Builders, but it has a practical



45.159

Figure 3-1.—Title block.



QTY	NOMENCLATURE OR DECRIPTION	PART NO. OR IDENTIFICATION NO	SPEC.	MATERIAL OR NOTE	ITEM NO.
1	FLEXIBLE INSULATOR			MUELLER NO. 26	9
2	MACHINE SCREW	9Z53'5-B12-6647		6-32 X 3/4 IN. LG. NYLON	8
1	PROTECTIVE SHIELD	9G9330-290-3462	MIL-P-15035	BAKELITE, TYPE FBE 38 IN X 48 IN. X 1/4 IN.	7
2	MACHINE SCREW	KZ5305-637-5884		4-40NC X 1/4 IN BRASS	6
1	SOLDER CONNECTION			SEE NOTE 3	5
1	MESH TEETH TEST CLIP			MUELLER NO. 24A OR EQUIV.	4
1	ROD	9Z9530-233-1299		1/4 IN. COPPER, BEND & FIT PER DRAWING	3
1	GROUND WIRE, 30 IN.			NO. 6 FLEXIBLE WIRE, COPPER	2
1	HANDLE, BAKELITE, 1-3/4 IN. DIA. X 18 IN.	9G9330-298-7538	MIL-P-79	BAKELITE 36 IN. LENGTH	1

1.1(26D)

Figure 3-2.—A bill of material on a drawing.

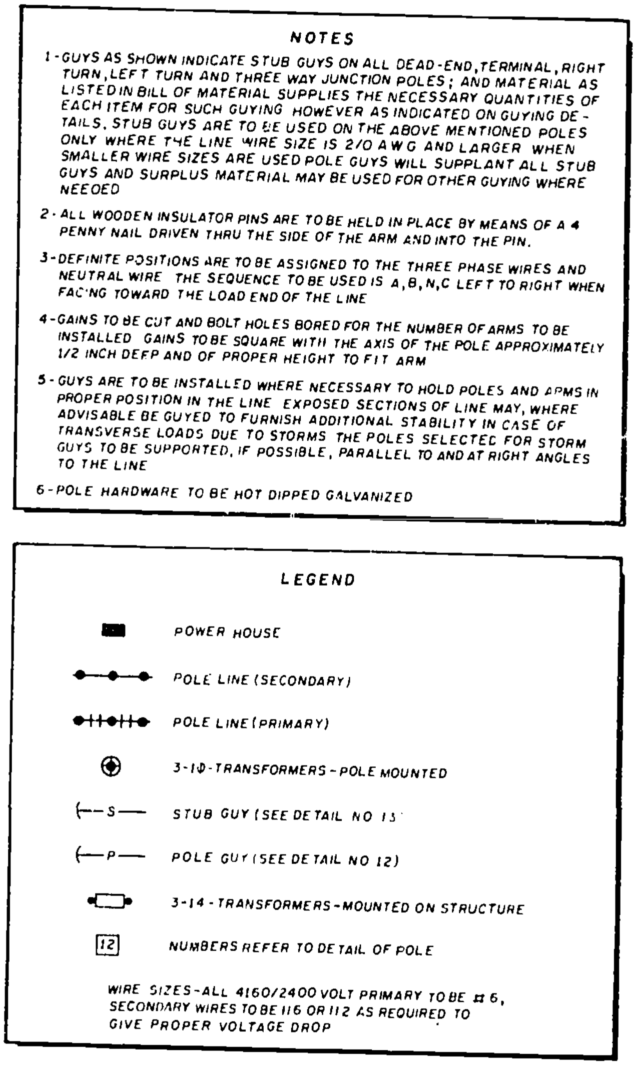
value to the Construction Electrician as well. The dimensions indicated on a drawing determine the amount of wire and conduit needed in a group of buildings. The number of poles to be erected can be figured by noting the distances between buildings.

Avoid measuring distance on a blueprint. Why? One reason is that the drawing may have been reduced in size from the original. Another is that the print may have shrunk or stretched. Whenever possible, you should READ the dimensions indicated on the drawings in preference to measuring the distance with a scale. If this is unavoidable, the graphic scale must be checked for possible expansion or shrinkage. Note especially if any details are drawn to a scale different than that of the rest of the drawing. Play it safe and READ dimensions; they always remain the same.

Notes and Legends

An example of the notes and legends which appear on a drawing is illustrated in figure 3-3. These notes contain equipment specifications, procedures for installing, and operating instructions. They may also contain explanations of parts of the drawing, and other pertinent information not included in the views themselves.

The legend lists the meaning of various symbols, abbreviations, and item numbers.



73.2

Figure 3-3.—Representative notes and legends.

This is a great help to the men of various ratings who may be engaged in the work, since not all of them would know the symbols well enough immediately to grasp the overall plan for the construction job. You will find legends a help when the drawings relate to a job where you must plan the laying of conduit and running of wire around plumbing fixtures, valves, duct work, or pipelines.

ELECTRICAL SYMBOLS

The number of symbols and abbreviations that may be used on drawings runs into the thousands. All draftsmen do not employ the same symbol to represent a particular item. These two facts can make blueprint reading a major task for any rating.

Fortunately, however, the Department of Defense prescribes MILITARY STANDARDS in this and other areas, which make for a high degree of uniformity in symbols employed in drawings used by the armed services. Graphic symbols for electrical diagrams are prescribed in the American National Standard Institute's Standard #Y32.9, dated 1972. Refer to table 3-1 which illustrates a number of electrical symbols used on drawings.

Use every opportunity you have to study the blueprints of the job to which you are assigned. Try to picture in your mind the item represented by each symbol. Trace the electrical circuits estimating the length of wire required for each circuit, and the locations of conductors and parts. When the lines, symbols, abbreviations, and notes make an understandable mental picture, you have learned to read an electrical drawing. Remember . . .if you do not understand what portions of the diagram mean, ask your supervising petty officer.

DIAGRAMS AND SCHEMATICS

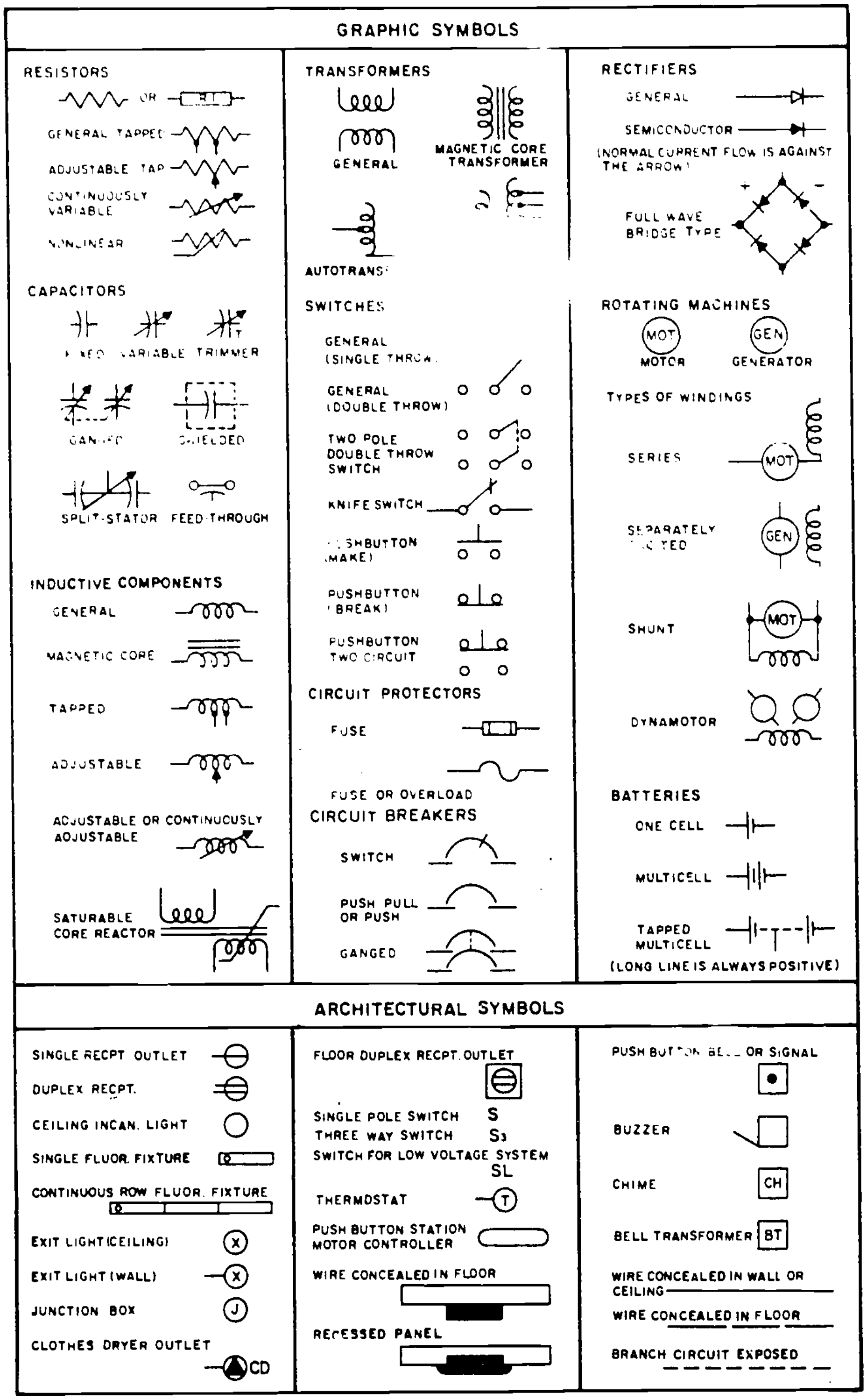
Construction Electricians, who know the trade, "talk with diagrams." When a technical question is brought up, a single diagram is often worth more than hours of discussion.

There are a number of types of electrical drawings. These may vary from wiring diagrams (scale drawings of electrical apparatus which show the exact location of all wiring and connections) to schematic diagrams and architectural plans.

In figure 3-4, a pictorial drawing, an elementary wiring diagram, and a schematic are compared. They show exactly the same thing, but they look quite different.

Let's see how diagrams prove their worth in voltage distribution, interior wiring, communications, and planning. Your work may involve you in any or all of these areas.

Table 3-1.—Electrical Symbols



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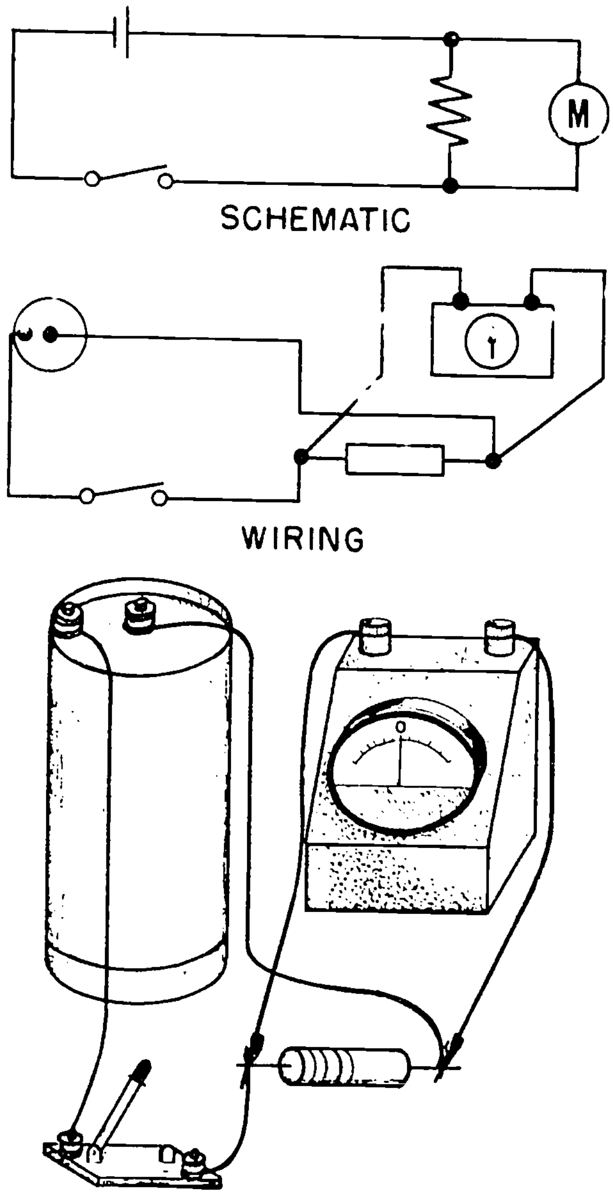


73.269
Figure 3-4.— Variety of diagrams.

EXTERNAL DISTRIBUTION SYSTEMS

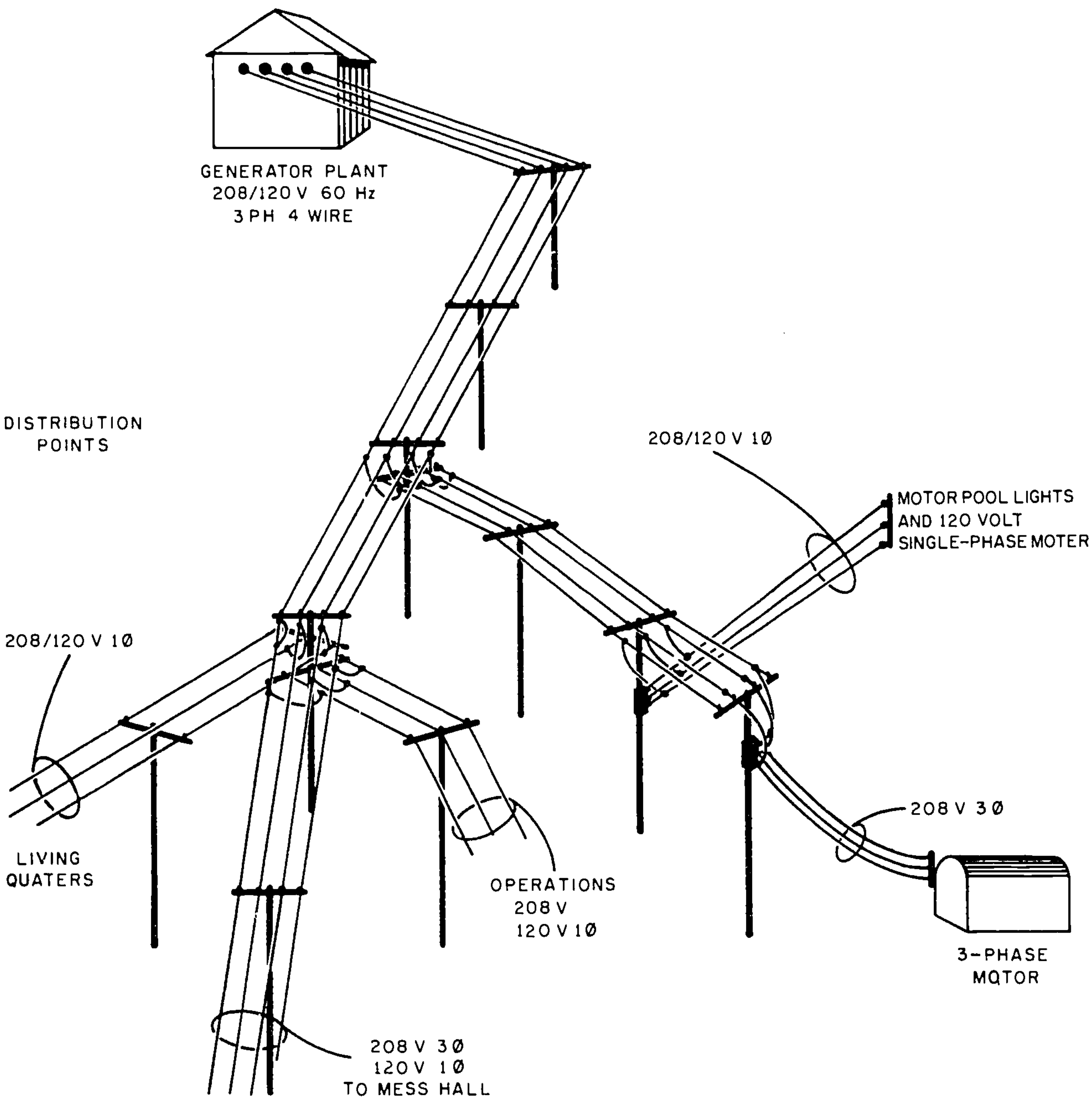
Figures 3-5 and 3-6 illustrate a pictorial and schematic view of a 3-phase/4-wire distribution system. Assume that the system has an alternator generating 208 volts. From the generating station, 3-phase/4-wire feeders carry the power overhead to the distribution points, from which primary mains branch off. One of these carries power to a lighting system and single-phase motor in a motor pool, both designed to operate on 120 volts, and to a three-phase motor designed to operate on 208 volts. The 208-volt three-phase motor is connected directly to the 208-volt three-phase main. For the lighting system and 120-volt motor, only single-phase power is necessary. Similarly, power is run to operational headquarters, living quarters, and mess hall.

A PLAN drawing is another type of drawing useful in exterior layout. The objects in views C and C of figure 3-7 are depicted as seen from directly above. In this way, the proportion and relations of the parts of the drawing to one another can be shown. The PLOT PLAN (fig. 3-7, view A) shows an area and gives the exact layout of various buildings, roads, equipment, and so on.

Figure 3-7, view A, is a plot plan showing five buildings which are to be supplied with electricity for power and lighting. An electrical layout has been superimposed. General notes (fig. 3-7, view B), one detail (fig. 3-7, view C) and section A-A (fig. 3-7, view D) of that detail are shown. The dotted line at the bottom of the drawing indicates underground ducts containing previously laid cable.

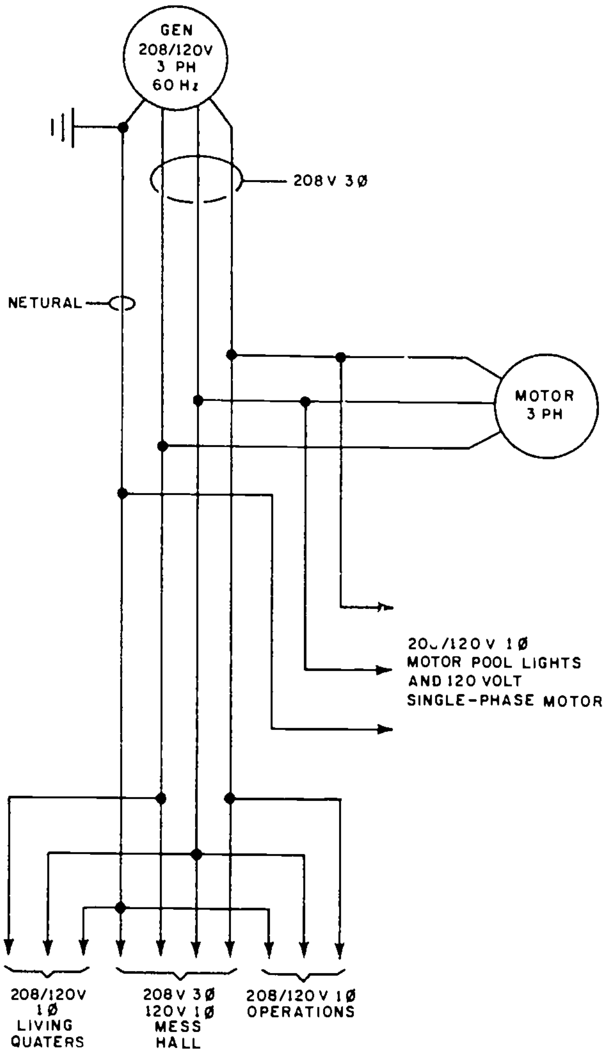
The design engineer has decided to tap the cable at manhole (M.H.) 22, and run lines from there overhead to dead end at the rear of building 126. Figure 3-7, view C, shows that lines are to be run underground from M.H. 22 to the first pole, up the pole to conductors on the pole crossarms. At building 126, lines are to be carried down the pole, regathered through a pothead into conduit again, and run underground to a concrete slab, and out through another pothead to a transformer bank. Where do you get this information? Refer to figure 3-8.

Figure 3-8 shows the detail B indicated in figure 3-7, view A. This represents the installation behind building 126, where the overhead line terminates. The last pole in the system is shown in the lower left corner. From the pole to the transformer bank, the underground conduit is indicated by dotted lines. The conduit runs underground to the concrete slab on which the transformers rest. Section A-A gives construction details of this slab.



82.71

Figure 3-5.—3-phase/4-wire distribution system, pictorial view.



82.72

Figure 3-6.—3-phase/4-wire distribution system schematic.

The angle-iron symbols in figure 3-8, with the dimensions 3" x 3", indicate that the BUS (connecting conductor) running along the transformer primaries will be supported on posts made of 3" x 3" angles. From the transformer secondaries, underground conduits (indicated by dotted lines) will run to the junction box on building 126.

Pay attention to the various notes and details indicated in drawings. Your life, and the lives of your coworkers, may depend on the care you take when reading and interpreting drawings.

INTERIOR WIRING

Figure 3-9 shows an electrical layout superimposed on an outline taken from an architectural floor plan. The service line bringing power into the house is a three-wire line in 1 1/4-in. conduit. However, the fact that the line voltage is 120/240 indicates that these three wires must be two hot wires and a neutral wire from a four-wire system. The third hot wire is not brought into the house.

The service line feeds power by way of a service switch to a lighting panel, from which three BRANCH CIRCUITS run to the lighting fixtures and convenience outlets in the rooms. The symbols for these fixtures and outlets, and of the service switch and the lighting panel, are shown at the bottom of figure 3-9.

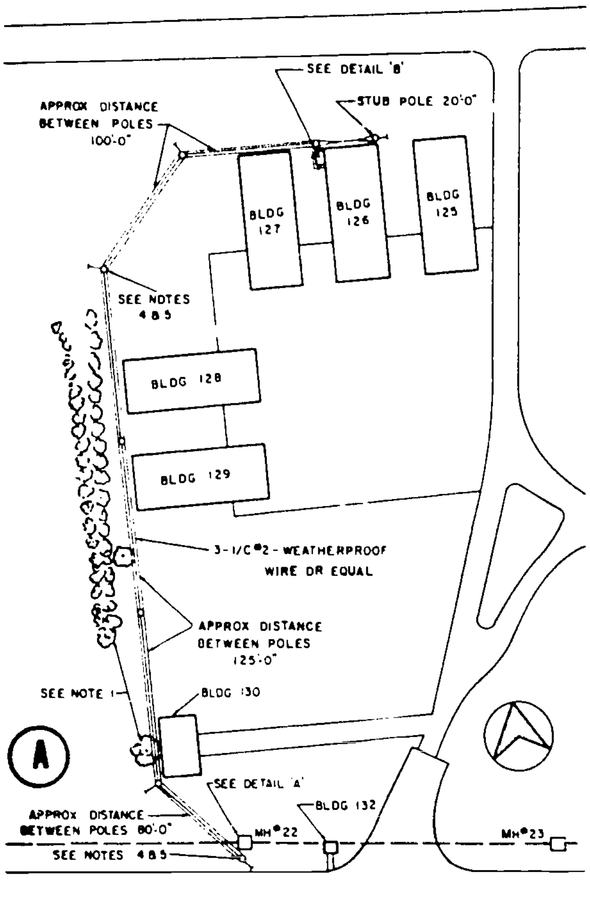
Figure 3-10 is a wiring diagram showing the connections for the layout shown in figure 3-9. After entering the building, the two hot wires (black) in the service lead are connected to and fused at the service switch, while the neutral wire bypasses the switch and runs to the NEUTRAL BAR in the panelboard, with a branch off to a waterpipe ground. Beyond the service switch, the two hot wires run to vertical LINE BARS in the panelboard.

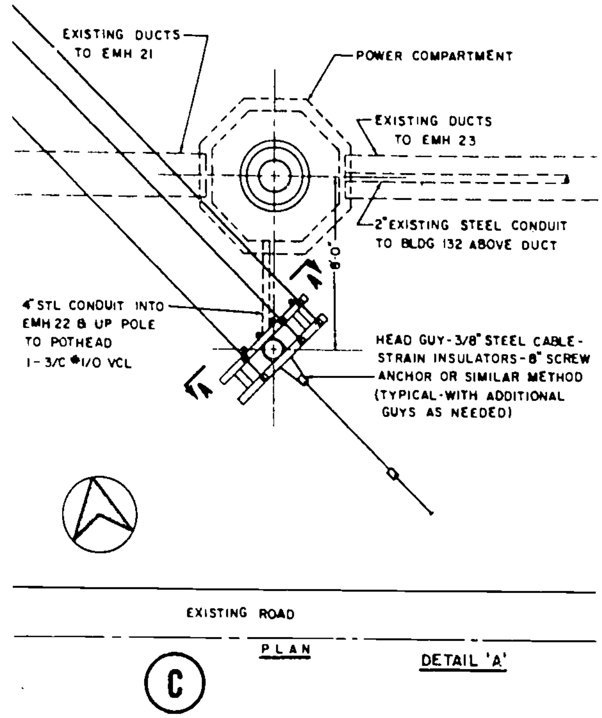
The panelboard is equipped to handle six circuits, with only three shown in the diagram. Consider branch circuit 4. It contains two wires, a hot wire running out from a circuit breaker in the panelboard, and a neutral (white) wire running back to the neutral bar in the panelboard. This circuit contains only a single switch, which turns all the lights in the circuit on or off simultaneously, but has no effect on the flow of power in circuits 2 and 6.

Circuit 2 similarly contains a hot wire out from the panelboard and a neutral wire back. Each of the lights in this circuit has its own switch, which controls the flow of power to that light only. Like circuit 6, circuit 2 has a hot wire out from the panelboard live bar, and a neutral wire back to the panelboard neutral bar.

WIRE COMMUNICATIONS

Schematics and wiring diagrams are used extensively in telephone communications. Figure

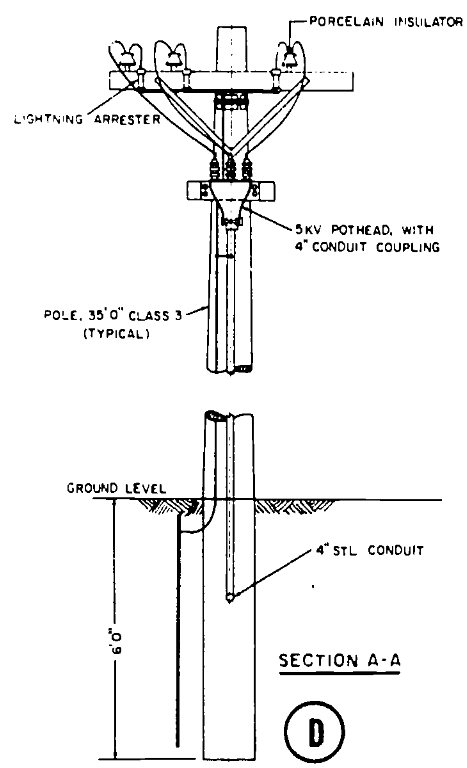




GENERAL NOTES

1 – TREES OBSTRUCTING POLE LINE TO BE TRIMMED OR REMOVED AS DIRECTED BY CONSTRUCTION OFFICER
2 – PROVIDE LIGHTNING ARRESTERS, AT EACH END OF POLE LINE, ON ALL THREE OVERHEAD WIRES GROUND LIGHTNING ARRESTERS WITH SUITABLE BARE WIRE CONNECTED TO DRIVEN GROUND ROD
3 – INSULATORS TO BE PORCELAIN, PIN TYPE, INSULATOR PINS TO BE LOCUST WOOD OR EQUAL
4 – TERMINAL POLES, AND POLES AT POINT OF CHANGE IN LINE DIRECTION, TO HAVE DOUBLE CROSS-ARMS. ALL OTHER POLES, SINGLE CROSS-ARM. CROSS-ARMS TO BE STANDARD 4 PIN, 5'-7" x 3 1/2" x 4 1/2", PIN SPACING 3'-0" ON CENTERS AND 14 1/2" ON SIDES
5 – TERMINAL POLES TO HAVE ONE GUY, POLES AT POINT OF CHANGE IN LINE DIRECTION TO BE GUYED ACCORDING TO STANDARD PRACTICE EACH GUY LINE TO HAVE TWO PORCELAIN STRAIN INSULATORS, THE LOCATION AND SPACING OF STRAIN INSULATORS AND GUY ANCHORS TO BE IN ACCORDANCE WITH STANDARD PRACTICE
6 – MATERIAL AND WORKMANSHIP SHALL CONFORM TO ALL STANDARD CODES, REGULATIONS AND SPECIFICATIONS LISTED IN NAVFAC SPECIFICATIONS

B



65.67
Figure 3-7.—Plot plan with electrical layout, general notes, detail and section drawings.

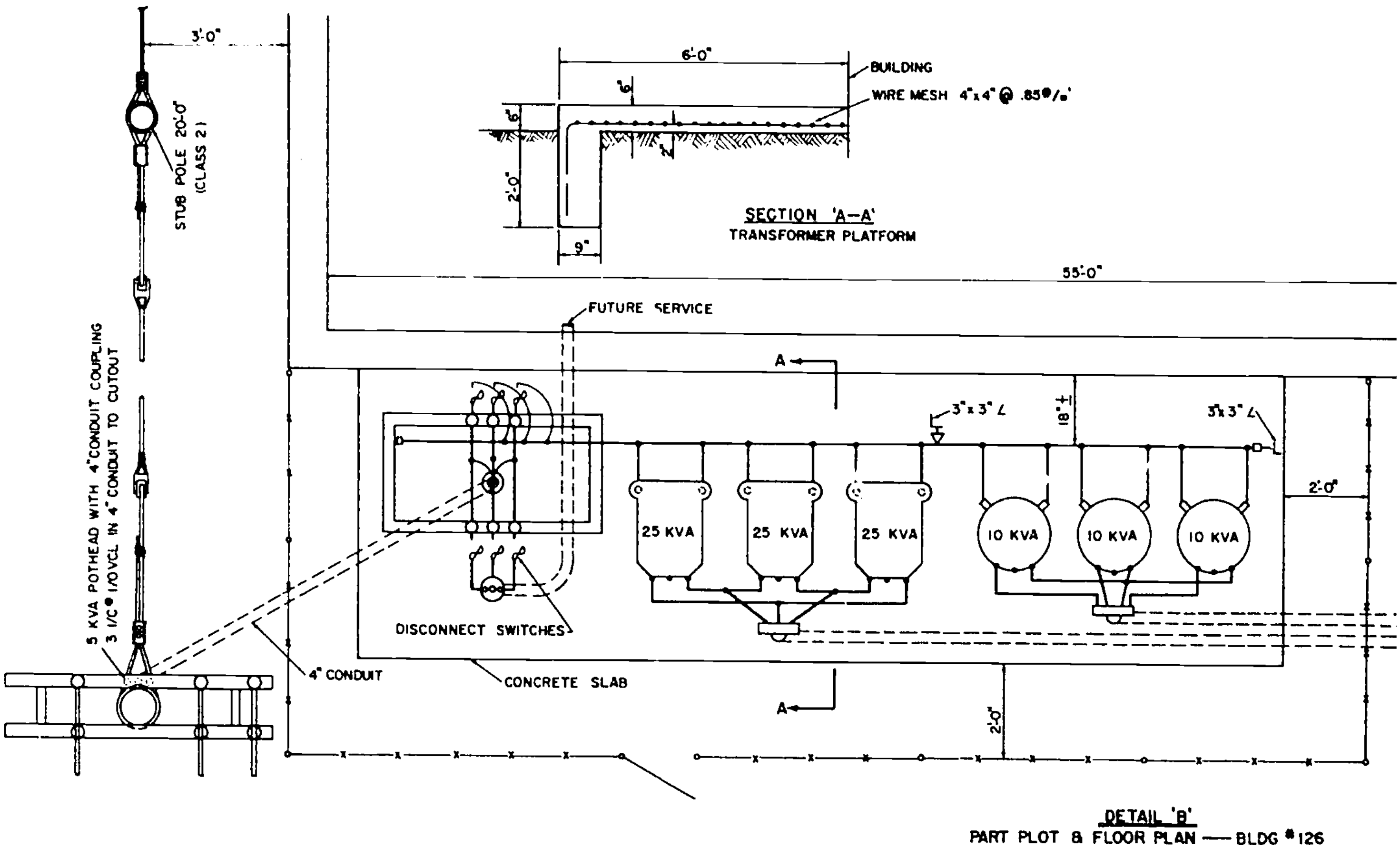


Figure 3-8.—Detail B indicated in figure 3-7.

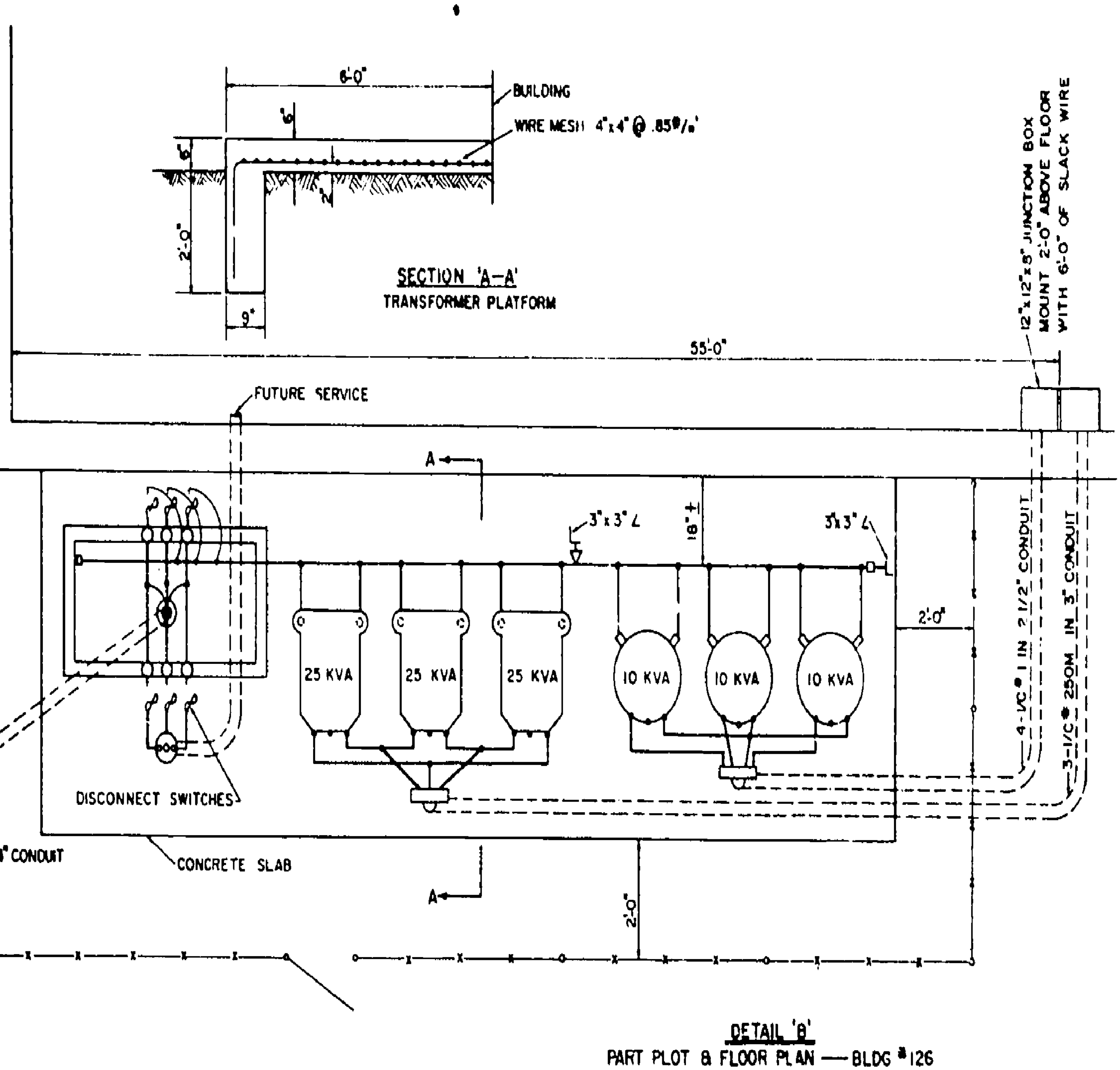
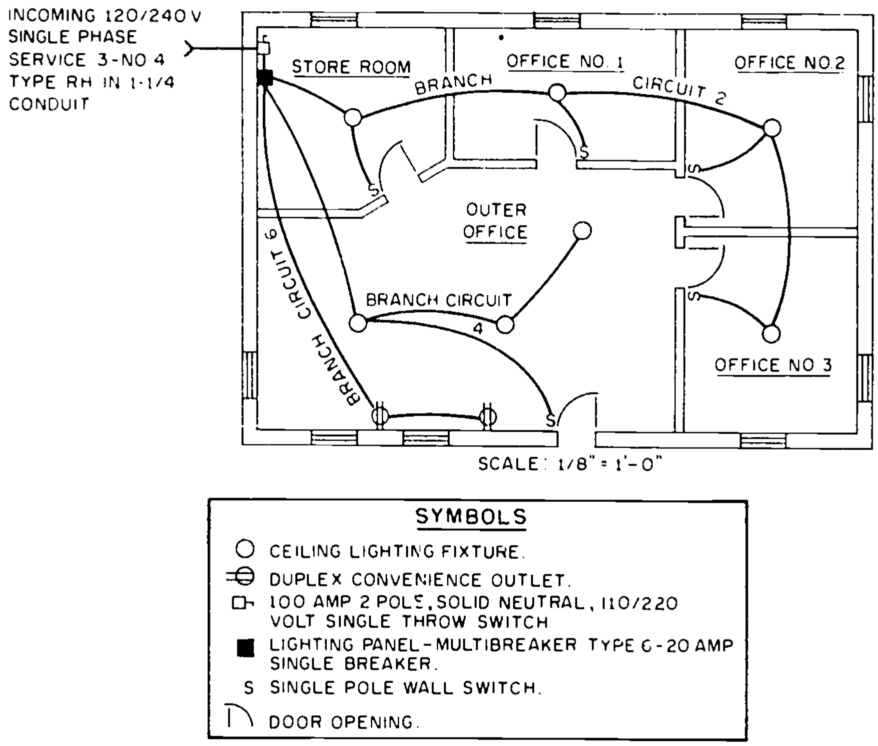
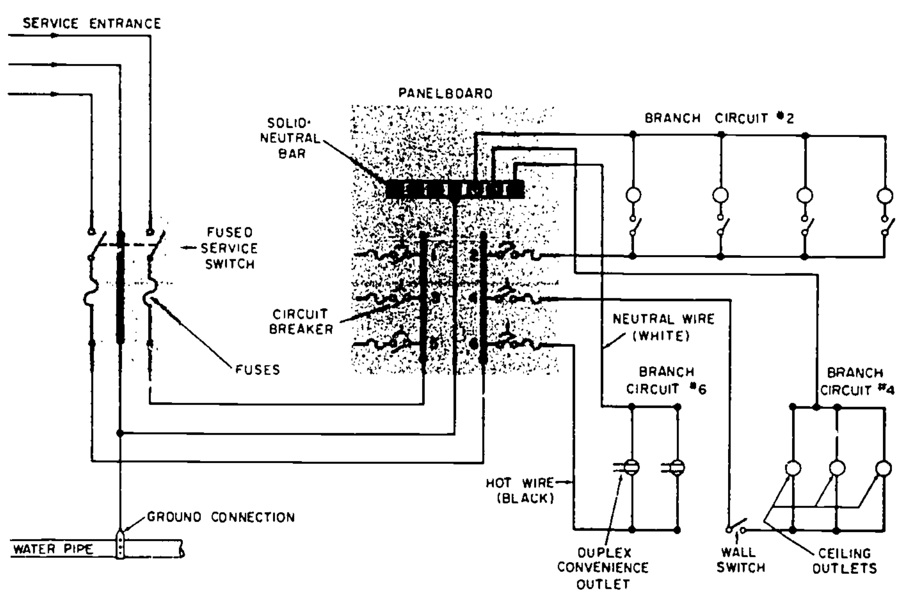


Figure 3-8.—Detail B indicated in figure 3-7. 65.69



45.515

Figure 3-9.—Inside electrical layout.



82.76

Figure 3-10.—Schematic for layout shown in figure 3-9.

3-11 shows a line circuit portion of a major switchboard circuit.

Section A shows the telephone set in its normal condition. The receiver is on the hook and all lamps and relays associated with this section are in their unoperated condition.

Section B delineates in bold lines what happens when a person at the calling station removes his receiver from the hook and the hookswitch contacts close. Battery, B1, sends current through the series circuit consisting of line relay LR1, the ring side of the line, the primary winding of induction coil P, the transmitter, and back to ground through the tip side of the line. Relay LR1 operates, closing the circuit of line lamp LL1, thus lighting the lamp.

As you can see from the above sequence of events, intelligent interpretation of schematics and diagrams will permit you to better understand and service telephone communication systems. Ask yourself when you encounter unfamiliar schematics, "What is the sequence of events? What relay energizes coil X or Y or Z? What is the normal current flow? What is supposed to happen?" As you ask and answer these questions, you will become more knowledgeable about circuit operations and functions.

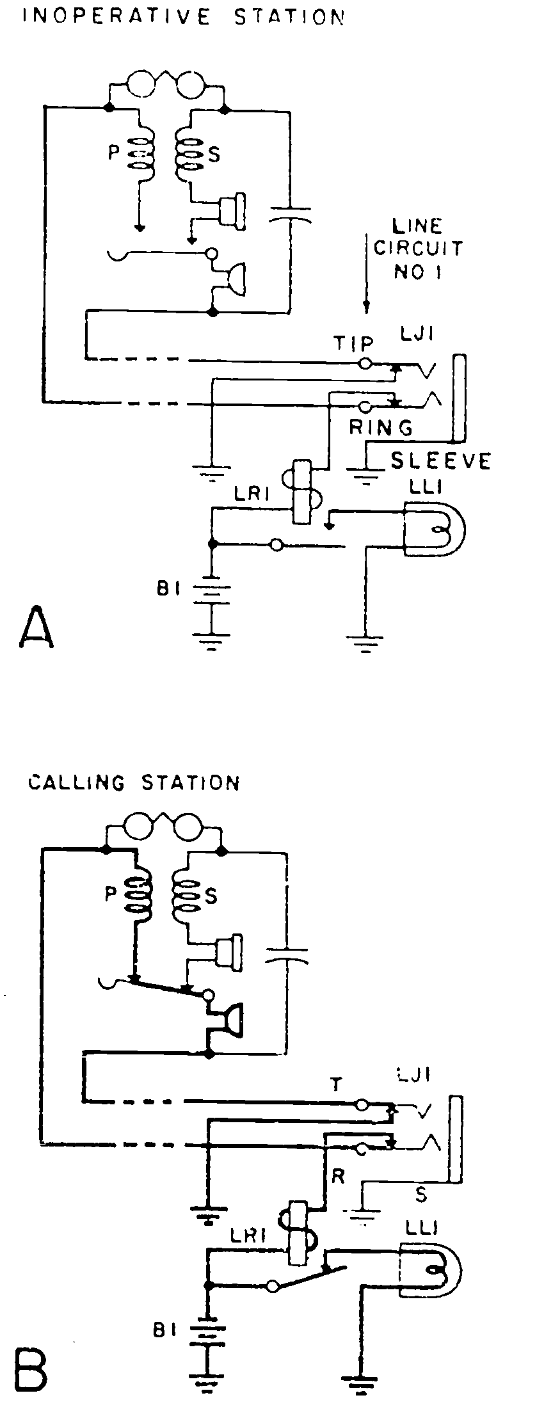
ELECTRIC APPLIANCE AND EQUIPMENT REPAIR

You may be required to install or repair the electric range or oven in the galley. How will you go about this task? Obviously, you will obtain the manufacturer's technical manual for the specific equipment you will be installing or repairing. Figure 3-12 shows a representative wiring diagram of one of these ranges.

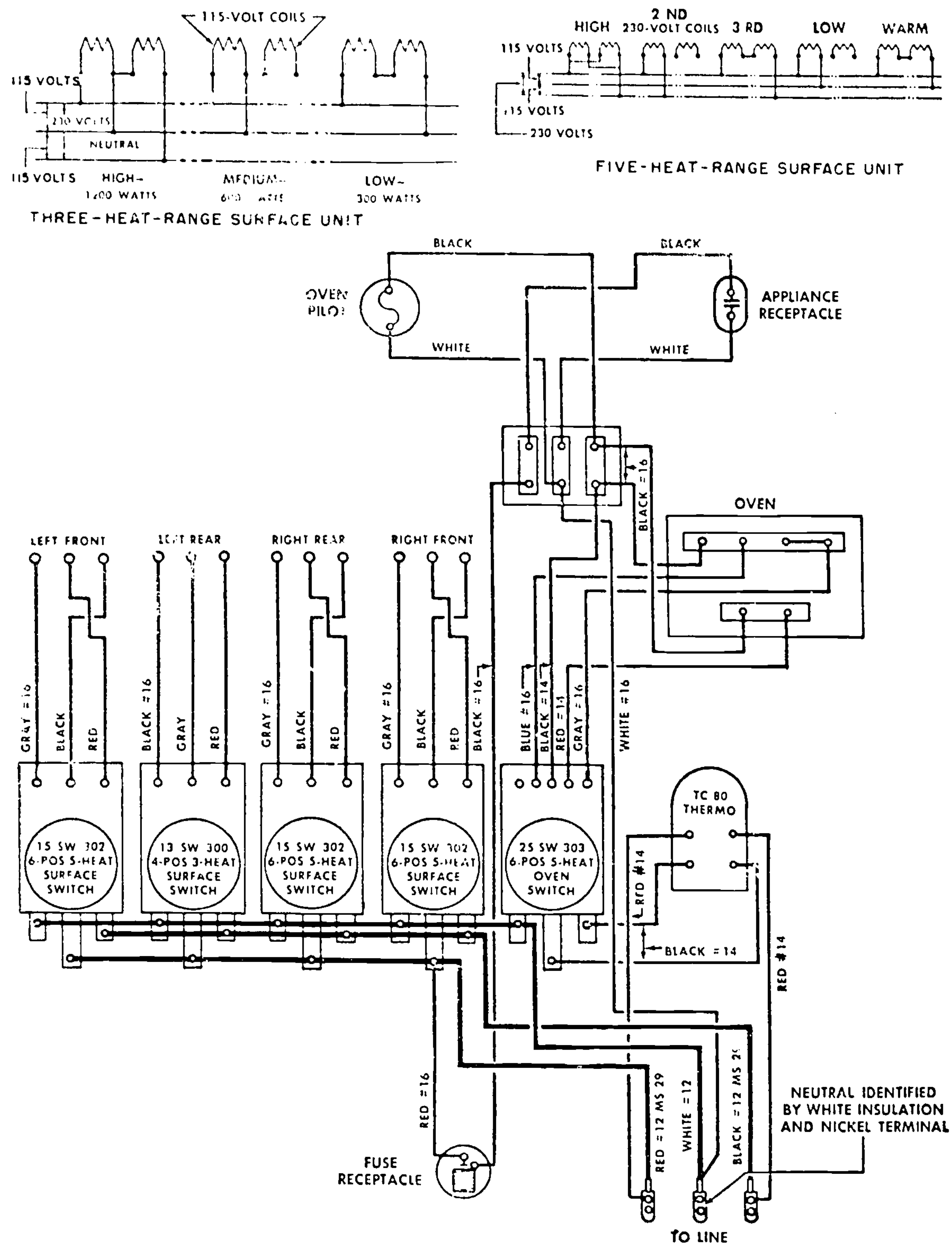
What will you do if you are required to install range or oven timers? Figure 3-13 and 3-14 are wiring diagrams for range and oven connections to timers. Notice how use of these diagrams will enable you to install or repair the appliances indicated much more readily than blindly trying to trace out the circuitry for the appropriate connections.

NAVAL FACILITIES ENGINEERING COMMAND DRAWINGS

The Construction Electrician very often works from a drawing prepared by the Naval

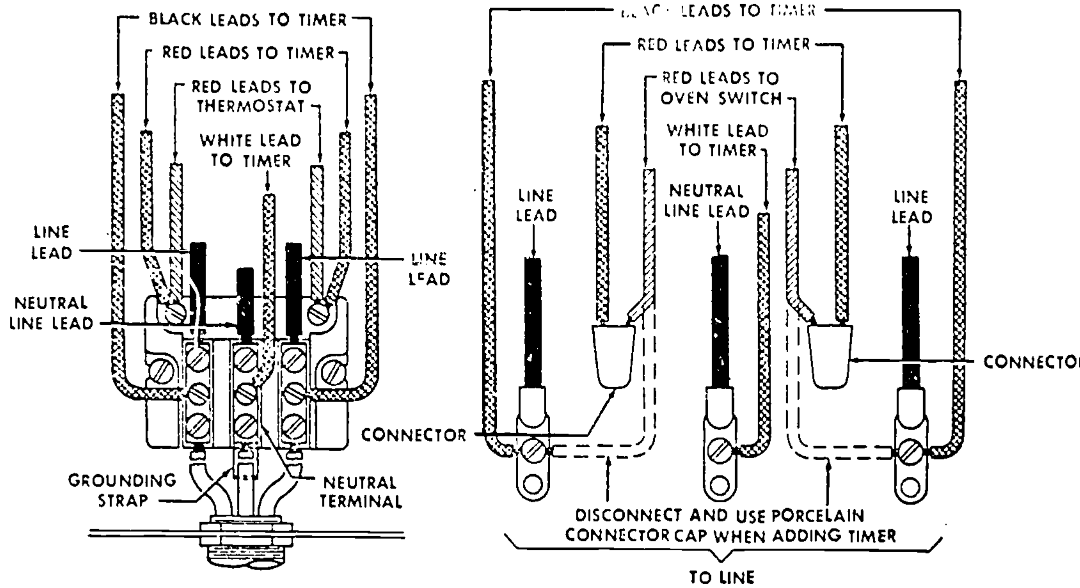


75.270
Figure 3-11.—Line circuit portion of switchboard.



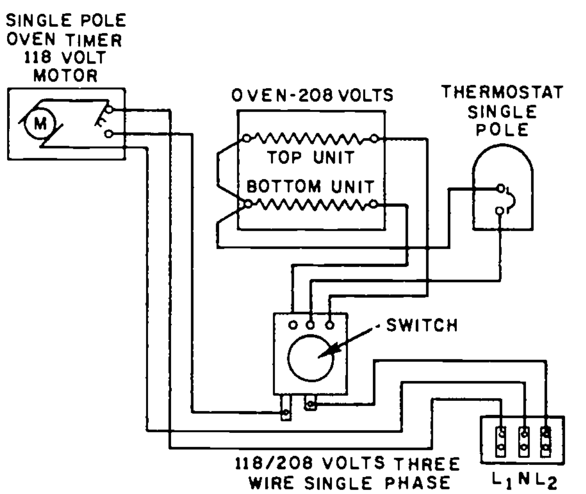
73.271

Figure 3-12.—Range wiring diagrams.



73.272

Figure 3-13.—Representative wiring diagrams for range timer connections.



73.273

Figure 3-14.—Representative diagram of electric range single-pole oven timer.

Facilities Engineering Command. Construction battalions seldom have the time or facilities for preparing a set of blueprints. For this reason, NAVFAC has prepared a series of drawings for use at advanced bases. This series of drawings is entitled Facilities Planning Guide, Volume I, NAVFAC P-437, and is kept in the operations or engineering office. These drawings cover most types of major installations. Copies are made available to all battalions before they leave the United States.

A complete set of drawings is usually composed of a number of separate drawings. The specific information which the drawings provide on proper installation of equipment and operating procedures will furnish satisfactory answers to many installation problems.

The standard drawings prepared by NAVFAC can save a surprising amount of time in the erection of a number of similar structures, and in wiring them for heating and lighting. For example, if a series of quonsets are to be erected, use of a standard plan enables the man in charge to put the various tasks on an assembly line basis, and makes it possible to erect an entire quonset town in less time than it would take to build an ordinary house.

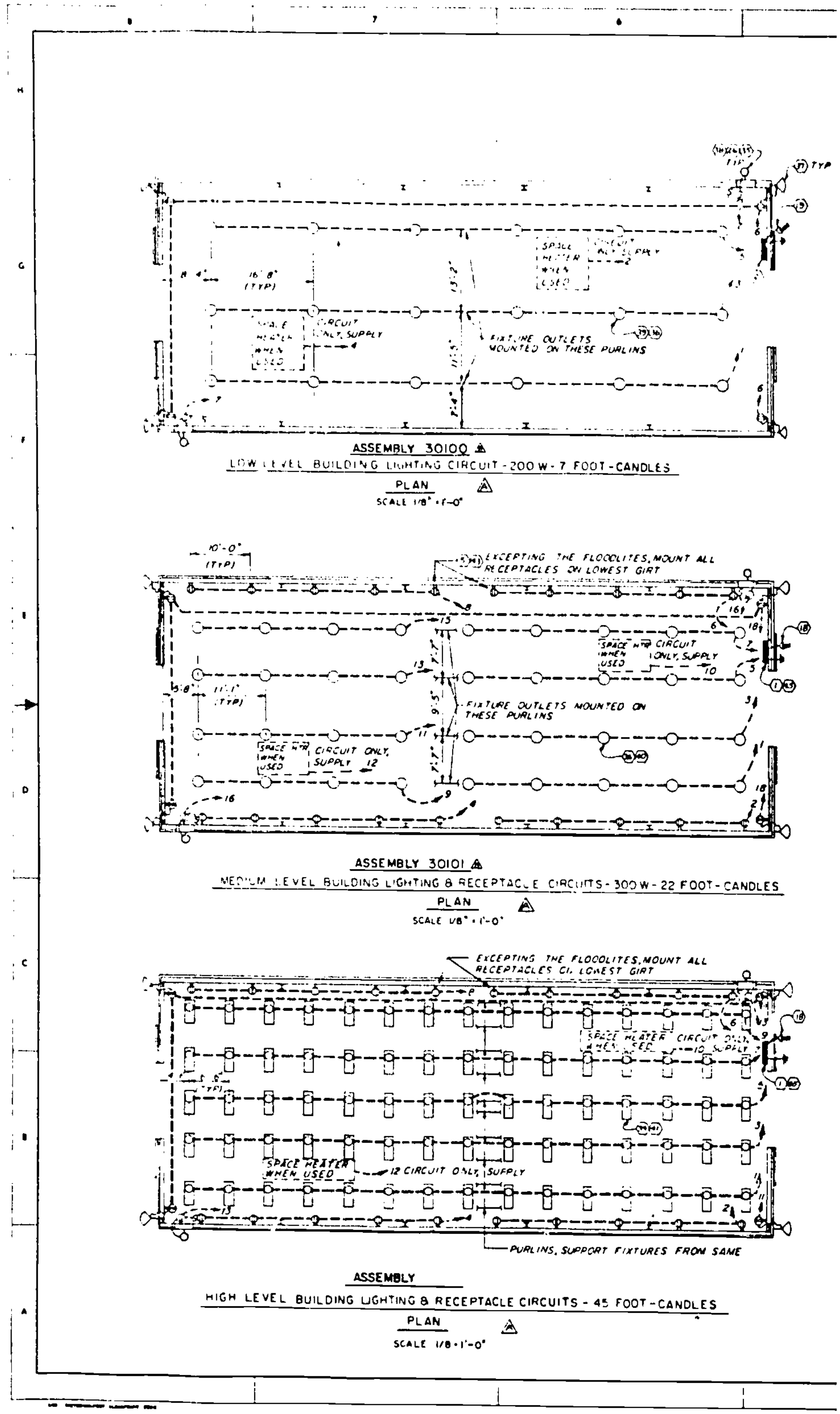
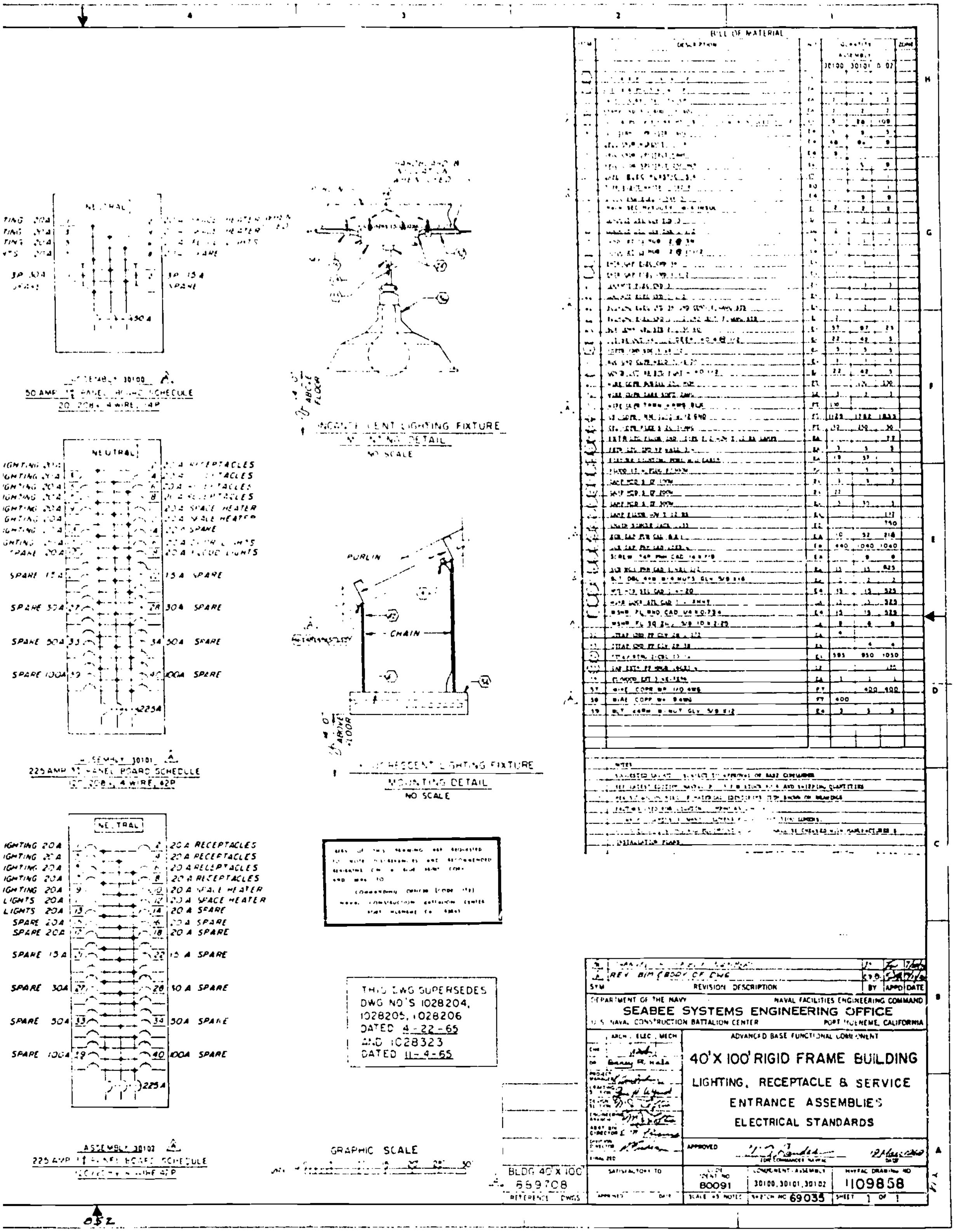


Figure 3-15.—40' x 100'



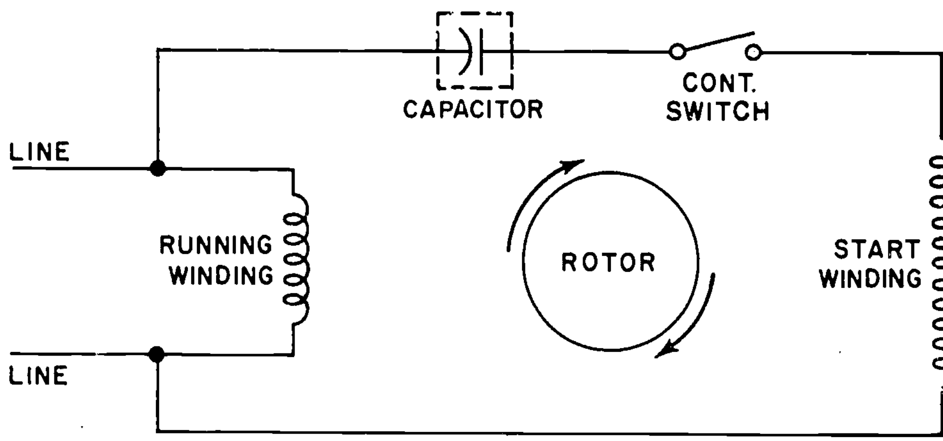
73.367

igid frame building assemblies.

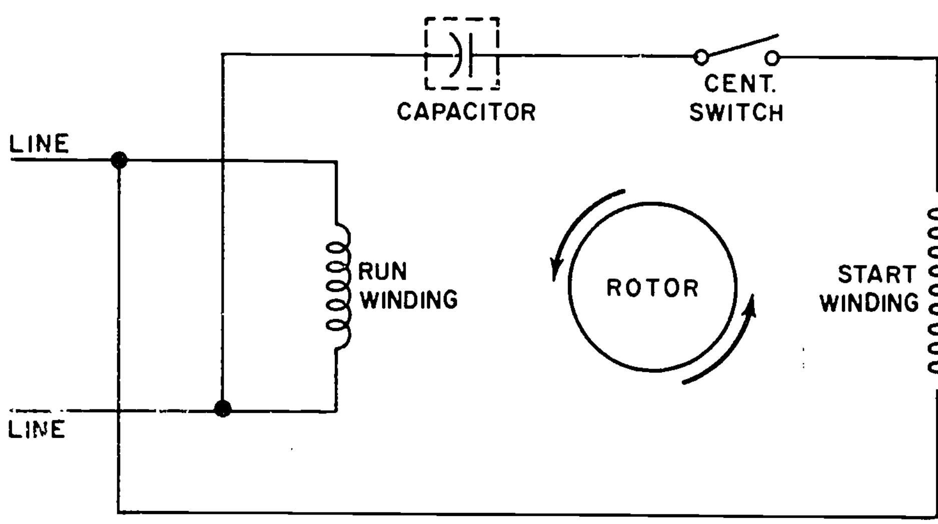
However, a single master plan cannot be used for all buildings. Changes are often necessary because of the use of the building and the type of machinery to be installed. Where shops are being erected, there will probably be at least one standard drawing for each type of shop.

Figure 3-15 is a standard drawing for a 40' x 100' rigid frame building being used for three different types of assemblies. All three assembly drawings show where the main panel is located, its size, the material needed to mount it, the number and types of lighting fixtures, the number of receptacles used, and any special details in its construction.

In studying the print, notice that each home run (return to panel circuit breaker) is given a number. This number indicates what circuit breaker this circuit will tie into in the main panel. The panel is numbered and each



73.368
Figure 3-16.—Freehand sketch of a single-phase capacitor start motor connected for clockwise rotation.



73.369
Figure 3-17.—Freehand sketch of a single-phase capacitor start motor connected for counterclockwise rotation.

circuit identified for general use and tie-in purposes.

The mounting details shown on the drawing for the incandescent lighting fixture are the mounting height above the floor (1-' 0") and the type of mounting used. For instance, number 25 (inside the hex symbol for the incandescent fixture) refers you to number 25 on the bill of material. The bill of material describes item number 25 as a junction box, octagon, 4" x 1 1/2" deep, with 4 knockout plugs for 1/2 inch connectors. Assembly 30100 will need 22 of these, 30101 will need 42, and 30102 will need three. Assembly 30102 will use fluorescent lighting, suspended by a chain 14' 0" above the floor. Like the example (number 25), all hardware used is indicated by numbers, which refer you to the bill of material for descriptions and amount.

The bill of material lists all items by number, description, unit and quantity for each assembly. The notes on the bottom of this bill give special instructions that will be useful when working on the job. For example, note 5 states: "Finished dimensions and equipment location shall be checked with manufacturer's installation plans." This could call for extra or special materials to install a special piece of equipment. You should be aware of this, because when changes are necessary, the deletion or addition should be shown on the appropriate print to keep them AS BUILT.

From studying prints of these assemblies and with a good knowledge of interior wiring, you should be able to wire up all three of these assemblies with the least amount of trouble and in the shortest time.

FREEHAND SKETCHES

Being able to redraw a circuit can be very helpful and necessary at times. An example of this could be changing the direction of rotation of a single-phase, capacitor-start motor which runs clockwise. You would want to reconstruct the circuit by drawing the running and starting coils according to the existing hookup. Then you would redraw the hookup the way it should be for the motor to run counterclockwise. (See figs. 3-16 and 3-17.)

CHAPTER 4

SPECIAL TOOLS

As a Construction Electrician, you must be able to use the special tools and equipment needed in your work. Among these are the portable power tools, such as drills and grinders, the pneumatic pavement breaker, power hacksaws, powder-actuated tools, air compressors, and earth augers.

BATTALION TABLE OF ALLOWANCE

In an NMCB, your portable tools will come from prepackaged kits which are part of the equipment allotted to a construction battalion for overseas deployment. The battalion's table of allowance (TOA) takes into consideration a manning level of 24 officers and 738 enlisted personnel in a wartime deployment and a northern temperate environment. Four men can work out of each prepackaged kit of tools. Part I of the TOA lists the battalion organic equipment and material. (See figure 4-1.) Part II consists of equipment and supplies controlled by COMCBLANT/COMCBPAC. The tools used by " " company shops and field crews come under Part I, section 6.

The contents of an electrician's tool kit are listed in figure 4-2, those of a lineman's kit in figure 4-3. Notice that the kits contain only basic handtools. (Power tools have to be checked out from the central toolroom.) The kits for a battalion's shops and maintenance platoon include plumber's kits, refrigeration kits, sheet metal kits, an electric arc welding kit, and miscellaneous equipment (fig. 4-4). As a crew leader or shops supervisor, you will be responsible for the checkout, control and inventory, and care and maintenance of these kits. COMCBPAC/COMBLANT Instruction 10290.2E covers the procurement, issue, and care of handtools and power tools; tool custody record cards; power tool preventive maintenance; and the drawing of sample tool kit boxes.

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 <u>Tools and Their Uses</u>, NAVPERS 10085-B, are discussed in this chapter.

Part I

(1) Personnel
(2) Weapons and Infantry Equipment
(3) NBC Warfare, Radiac, Damage Control, and Safety Equipment
(4) Administrative and General Services
(5) Maintenance Tools and Shop Equipment
(6) Construction Tools and Kits
(7) Construction Oriented Consumables
(8) Mount-out Material and Containers
(9) Clothing and Bedding
(10) Medical and Dental
(11) Communication and Test Equipment
(12) Forms and Publications

Part II

(20) Civil Engineering Support Equipment (CESE)
(21) Facilities
(22) Collateral Equipment for Facilities
(23) Petroleum-Oil-Lubricants (POL)
(24) Provisions
(25) Repair Parts
(26) Tactical Support Facilities
(27) Contingency Support

Figure 4-1.—Battalion Table of Allowance.

SOLDER 50/50 ROSIN 3/32	1 LB
SOLDERING GUN ELECTRIC	1 EA
STRIPPER CABLE F/TYPE NM	4 EA
BRACE BIT RATCHET 12	1 EA
PLIERS DIAGONL CUT 7 1/2	4 EA
FILE AMPAT RD BAST 10	1 EA
KNIFE POCKET W/SCDR-SCRPR	4 EA
FILE AMPAT REG TPR 7	1 EA
STRIPPER WIRE ELECTRIC 10/18 AWG	4 EA
BLADE HACKSAW 18T 12LG	2 BD
BLADE HACKSAW 32T 12LG	2 BD
FRAME HACKSAW ADJ 10-12	2 EA
SAWS NEST KEY-COMPS-NAIL	1 SE
HOLDER FILE TOOL ADJ JAWS	2 EA
CHISEL SET BUTT WOOD W/RL	1 SE
PLIERS SLIP JOINT 11-1/4 LG SMOOTH JAWS	4 EA
SCREWDRIVER OFFSET 1/4N 5 1/4N OA	2 EA
AWL SCRATCH 3 1-2	4 EA
SCREWDRIVER COMM 1/4X4N	4 EA
PULLER FUSE 0-100 AMP	1 EA
SCREWDRIVER CABINT 3/16X6	4 EA
SCREWDRIVER FLAT TIP MGNTIC 1/8X2N	4 EA
SCREWDRIVER PHILIP NO 3 TIP 6N BLADE	4 EA
SCREWDRIVER PHILIP NO 2 TIP 4N BLADE	4 EA
PLIERS LINEMAN 8N	4 EA
WRENCH OE ADJ 8N	4 EA
PULLER FUSE 100-600 AMP	1 EA
PLIERS LONG NOSE 6N	4 EA
SCREWDRIVER CABINT 3/16X8 3/16X8N	4 EA
WRENCH OE ADJ 12N	2 EA
WRENCH PIPE 10N	2 EA
WRENCH V-GRIP PLIER 8 1/2	4 EA
SCREWDRIVER START 1/4X6	4 EA
SCREWDRIVER FLAT TIP 3/8X8N	4 EA
SCREWDRIVER FLAT TIP 5/16X6N	4 EA
PUNCH CENTER 3/8X4	1 EA
PUNCH CENTER 1/4X3 1/4 NO 2	1 EA
HAMMER HAND OUTLET BOX	4 EA
WRENCH SET SOCKT SPINNER	2 SE
SCREWDRIVER STUB FLAT TIP 1/4X1 3/4N	4 EA
KEY SET SCKT HEAD SCREW	1 SE
DRILL ELEC PORT 1/2	1 EA
DRILL SET TWIST 1/16 TO 1/2 BY 16THS	1 SE
BIT SET AUGER 1/4 TO 1 N	1 SE
TOOL BOX STL MECHANIC	4 EA
POCKET ELEC TOOL	4 EA
TAPE MEASURE FLEX 10FT	4 EA
RULE WOOD FLDG H-DTY 72N	4 EA
LEVEL AND PLUMB 9N	1 EA
INDICATOR LINE VOLTAGE	4 EA

Figure 4-2.— Electrician's tool kit list for four men (80006).

BLOCK AND TACKLE 1/2 F-RP	2 EA
BAG LINEMAN GLOVE	4 EA
CLIMBERS TREE-POLE WITH STRAPS AND PADS	4 SE
CLIMBER STRAP AND PAD SET	4 SE
STRAP SFTY NYLON 1-3/4X84	4 EA
BELT TOOL LINEMAN SZ 36	1 EA
BELT TOOL LINEMAN SZ 38	2 EA
BELT TOOL LINEMAN SZ 40	1 EA
FILE AMPAT FLT SMTH 12	2 EA
BRACE BIT RATCHET 12	1 EA
CHISEL COLD 3/4	2 EA
FILE AMPAT MILL BAST 12	2 EA
KNIFE LINEMANS FLDNG 3	4 EA
BLADE HACKSAW 18T 12LG	1 BD
BLADE HACKSAW 24T 12LG	1 BD
FRAME HACKSAW ADJ 10-12	2 EA
HOLDER FILE TOOL ADJ JAWS	2 EA
CHISEL FIRMER 2N	2 EA
CHISEL SET BUTT WOOD W/RL	2 SE
HAMMER HAND ENG 2 1/2 LB	2 EA
SCREWDRIVER FLAT TIP 3/8X12N	4 EA
PLIERS LINEMAN 8N	4 EA
WRENCH OE ADJ 8N	4 EA
WRENCH OE ADJ 12N	4 EA
WRENCH LINEMAN DBL	4 EA
PLIERS SLIP JOINT 10N	4 EA
SCREWDRIVER FLAT TIP 3/8X8N	4 EA
SCREWDRIVER FLAT TIP 5/16X6N	4 EA
HAMMER HAND CARP 20 OZ RIPPING FBR GLS HNDL	2 EA
BIT AUGER SHIP 11/16X29	2 EA
BIT AUGER SINGLE SPUR CAR W/SCREW POINT 9/16X18N	2 EA
BIT AUGER SINGLE SPUR CAR W/SCREW POINT 7/16X18N	2 EA
BIT AUGER SINGLE SPUR CAR W/SCREW POINT 11/16X18N	2 EA
BIT AUGER SINGLE SPUR CAR W/SCREW POINT 13/16X18N	2 EA
BAG TOOL SATCHEL CANVAS 24X14X6N	4 EA
BAG BOLT NUT W/BELT LOOP	1 EA
RULE WOOD FLDG H-DTY 72N	4 EA
TAPE MEASURE CHROME 100FT GENERAL PURPOSE	1 EA
TAPE ELEC PLASTIC 3/4	2 RO
HOOK PULLING STRANDVISES	2 EA
PROTECTOR RUBR GLV	4 PR
GLOVE ELEC RUBBER SZ 10	2 PR
GLOVE ELEC SZ 11	2 PR
GLOVE LINEMANS LTHR	4 PR

Figure 4-3.— Lineman's tool kit list for four men (80007).

GRINDING MACH BNCH 1X7WHL	2 EA
TORCH OUTFIT CUTNG-WLDNG	4 EA
BENDER PP-COND HY 1 1/2-4	1 EA
THREADING MACH PIPE-BOLT PORT 1/8-2PP 1/4-1 BOLT	2 EA
BLADE HOLE SAW 2N	1 EA
BLADE HOLE SAW 3/4N	1 EA
BLADE HOLE SAW 7/8N	1 EA
BLADE HOLE SAW 1N	1 EA
BLADE HOLE SAW 1 1/8N	1 EA
BLADE HOLE SAW 1 1/4N	1 EA
BLADE HOLE SAW 1 3/8N	1 EA
BLADE HOLE SAW 1 1/2N	1 EA
BLADE HOLE SAW 1 5/8N	1 EA
BLADE HOLE SAW 1 3/4N	1 EA
BLADE HOLE SAW 1 7/8N	1 EA
ARBOR HOLE SAW NO 1 5/8X1 1/8N	1 EA
ARBOR HOLE SAW NO 2 1 1/4X4 1/2N	1 EA
ARBOR HOLE SAW NO 3 1 1/4X4 1/2N	1 EA
GRINDER ATTACH DRILL TWST	1 EA
TRUCK HAND LIFT PALLET TYPE 4000 CAP HYD	1 EA
TRUCK HAND 2 WHL 500 CAP	1 EA
TAIL LINE ASSY SFTY BELT	12 EA
BELT TOOL LINEMAN SZ-42	20 EA
COMPRESSOR 15CFM 175 PSI SHOP EMD 208V 60HZ 3 PH	2 EA
HOSE ASSY KIT AIR COMP 15-40CFM SHOP	2 EA
OVEN WELD ELCTRD STORAGE	2 EA
SPRAY PAINT OUTFIT W/COMP	1 EA
CUTTER TPR JNT ASB CEM PIPE PRESSURE 3-6 INCH	1 EA
SAW MITRE BOX 11PT 26	4 EA
MITER BOX W/O SAW	4 EA
PUNCH-DIE SET KNOCKOUT 2-2 1/2IPS F/1 15/16-2 3/8N HOLE SIZE	4 SE
PUNCH-DIE SET KNOCKOUT 1/2-1 1/4IPS F/7/8-1 11/16N HOLE SIZE	4 SE
CUTTER TPR JNT ASB CEM PIPE NON-PRESSURE 3-6 INCH	1 EA
PUNCH-DIE KNOCKOUT 2 1/2IPS F/2 7/8N HOLE SIZE	3 EA
PUNCH-DIE KNOCKOUT 3 1/2IPS F/4N HOLE SIZE	2 EA
PUNCH-DIE KNOCKOUT 3N IPS F/3 1/2N HOLE SIZE	3 EA
STICK CLAMP HOT LINE	2 EA
TAPE FISH POLYETHYLENE 50FT W/REEL	3 EA
TAPE FISH POLYETHYLENE 100 FT	3 EA
FLATTER 2 1/2X5 BLKSMITH	1 EA
SHOVEL RD PT LG HNDL	10 EA
VISE SHT MTLWKR 9	2 EA
VISE WOODWORKERS 12	4 EA
STAKE SHT MTL BLOWHORN	2 EA
VISE BENCH 4 1/2N JAWCOMB	2 EA
PIKE POLE 14FT LG	8 EA
BENDER CONDUIT 1-1 1/4	6 EA
SHOVEL SQ PT D HNDL	4 EA
PLATE BENCH MTLWKR	2 EA
HAMMER HAND BLKSMTH 3LB CROSS PIEN	2 EA
BENDER CONDUIT 1/2-3/4	8 EA
DRESSER WHL ABR W/X CTRS	2 EA
JACK REEL HAND	4 EA
HAMMER HAND BLKSMTH SET	1 EA
TAPE FISH 1/8X100	2 EA
ANVIL BLACKSMITH 200LB	1 EA
STICK HOT LINE	2 EA
SHOVEL SQ PT LG HNDL	15 EA
HANDLING TOOL SHT MTL VACUUM CUPS	2 EA
STAKE SHT MTL CANDLE MOLD	2 EA
BENDER EMT 1N	5 EA
BENDER EMT 1/2N	6 EA
BENDER EMT 3/4N	6 EA
DRESSER WHL ABR ROTARY	2 EA
ATTACHMENT SET SPEED REDC	4 EA
SHEAR MTL CUTNG ELEC PORT	2 EA
SHEAR MTL ELEC 16GA	2 EA
ETCHER ELEC PORT VIBRATOR	1 EA
TOOL BOX 18X10X13N MECH	3 EA
CHEST SHT MTL WKR STL	2 EA
STEPLADDER FIBERGLASS 12F F/ELECTRICIANS USE	1 EA
STEPLADDER FIBERGLASS 8F F/ELECTRICIANS USE	1 EA
STEPLADDER FIBERGLASS 6F F/ELECTRICIANS USE	1 EA
LADDER EXTENSN 30F	2 EA
STEPLADDER ALUM ALLOY 6FT	5 EA
STEPLADDER ALUM ALLOY 8FT	5 EA
STEPLADDER ALUM ALLOY 12F	1 EA
INSULATOR HOSE ELEC	4 EA
INSULATOR HOOD ELEC	4 EA
BLANKET LINEMAN	4 EA
TESTER PORT ELEC TOOL MULTI-AMP B2500	1 EA
SCALE BEAM INDICAT 1200LB	1 EA
METER AIR VELOCITY 0-1000 FPM	1 EA

Figure 4-4.—Miscellaneous "B" company equipment (83002).

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. The following paragraphs concern the pneumatic drill and pneumatic grinder, probably the most widely used portable air-powered tools. As an Electrician, you will be required to maintain the portable pneumatic tools as well as use them.

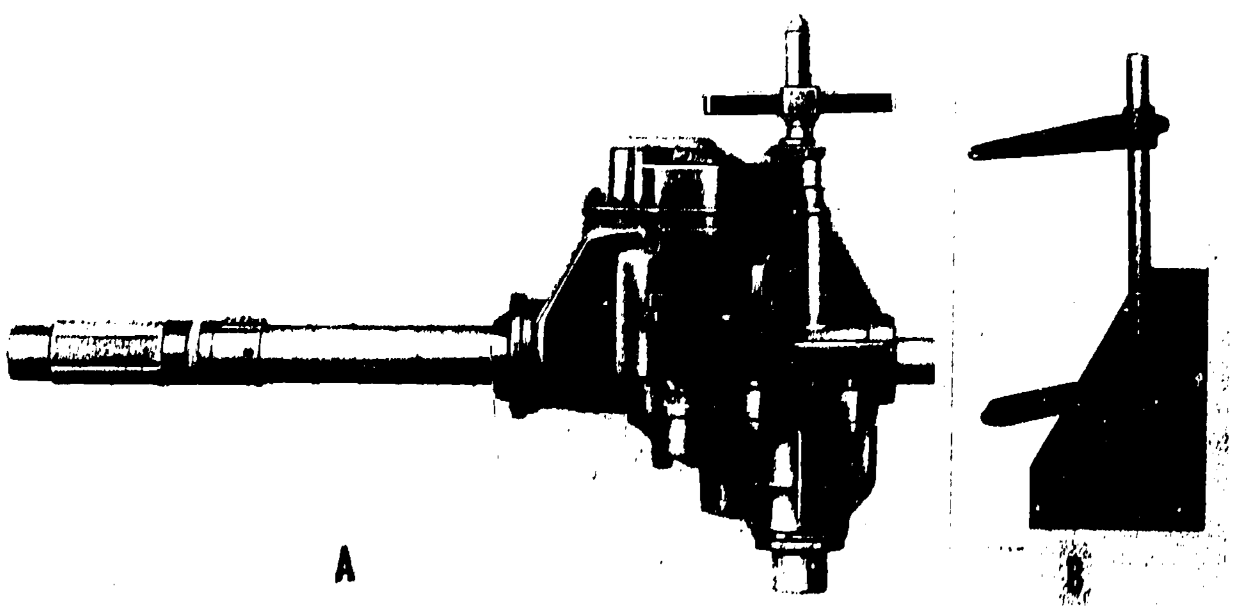
PNEUMATIC DRILL

The heavy-duty pneumatic drill, shown in view A of figure 4-5, 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 4-5. When you drill a hole using the pneumatic drill with the OLD MAN, make sure you wear goggles during the drilling operation. Before connecting the airhose to the drill, blow out any foreign matter that may be in the hose. Next connect the hose and drill, and turn on the air at the compressed air outlet. Then turn on the drill and test run it. 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.

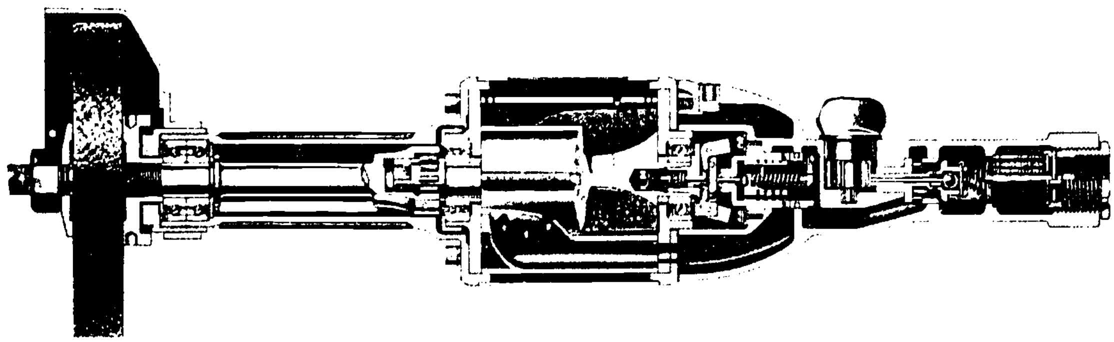
PNEUMATIC GRINDER

The pneumatic grinder, shown in figure 4-6, 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 grinding surface of the wheel is square with the surface of the material being ground.



11.6

Figure 4-5.—Heavy-duty pneumatic drill and stand.



11.8X

Figure 4-6.—Sectional view of a pneumatic grinder.

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 require 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 check the lubricator regularly 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. If you use heavy oil, you will have to clean your tool in cleaning solvent to loosen the gummy substance. You will then have to 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 operating portable power tools, observe applicable safety precautions. A partial list of safe practices follows:

1. Always wear your goggles when working with these tools.
2. Do not 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, do not 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, make sure the extension cord is not energized when the tool plug is inserted in or removed from the extension cord. Use only 3-wire cord and grounded plugs.

PNEUMATIC PAVEMENT BREAKER

A PNEUMATIC PAVEMENT BREAKER (fig. 4-7) may be used on construction projects to demolish structures made of concrete, b[illegible], asphalt, and the [illegible]; it is also used for general rock breaking. With attachments, it can be used for digging and tamping as well.

Five attachments for the pavement breaker are the moil point, chisel point, tamper, pick, and spade. (See fig. 4-7.) The moil point is a dev[illegible] for breaking through concrete, stone, or other dense and abrasive material. The chisel point will cut asphalt, frozen ground, or extremely hard earth. The tamper is used to compact loose material.

The spade, shaped like a garden spade, is used for digging trenches, preparing footings or foundations, digging caissons, or general digging that is too difficult and slow for an ordinary hand spade. The pick will dig into frozen ground, cemented gravel, or other material too hard to be penetrated by the spade.

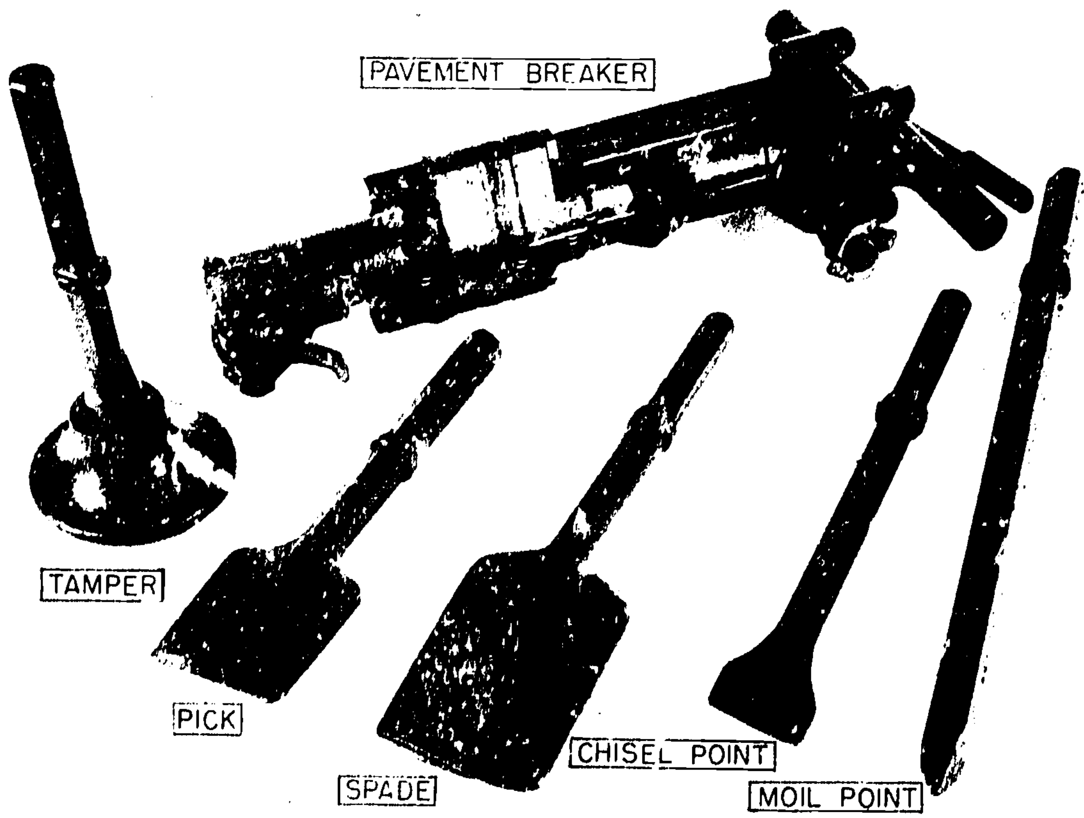
Operation

Pneumatic tools are simple to operate, and the average SEABEE can be taught to operate any of them in a relatively short time. In most cases, however, operators have little mechanical knowledge, so close supervision is required.

Since pneumatic tools are heavy and vibrate a lot during use, they tend to tire out their operators, especially the inexperienced ones. The operators should be strong and in good physical condition.

Hold the pavement breaker down while it is in operation, but use only sufficient pressure to guide the tool and keep it in place. Leaning heavily on the pavement breaker will only shorten the stroke of the tool attachment and result in less work being performed.

The shank of each attachment used with the pavement breaker must be the correct size. Using improper shank sizes will reduce the effectiveness of the blow and damage the pavement breaker.



127.267

Figure 4-7. -- Pneumatic pavement breaker and accessories.

Pavement breakers can best be operated in tandem. In operating, take only small bites (4 to 3 inches behind the working face). If a moil point becomes stuck, use the second breaker to break the material binding the point. When the breaker is being used singly and the point becomes stuck, take the pavement breaker off and use another point to free the stuck point.

Keep the work area clear of broken material so that it does not interfere with efficient operation of the tool.

Make sure you are using the right attachment. Trying to drill holes with the moil point will result in breaking the point. The chisel point issued with the breaker is designed for cutting asphalt and soft materials. If it is used for breaking concrete, the point will be damaged beyond repair.

A careless operator can quickly break the tool latch retainer bolt by not shutting off the tool when the moil point breaks through concrete. When this happens the front head bounces on the concrete, resulting in a broken retainer bolt.

Maintenance

With proper maintenance, a pavement breaker can be kept in good operating condition. It certainly helps to sharpen the points of all attachments, and to keep them sharp. Check the airhose connections to the pavement breaker often to make sure no air is escaping. Check to see that all nuts and bolts are tight.

Safety Precautions

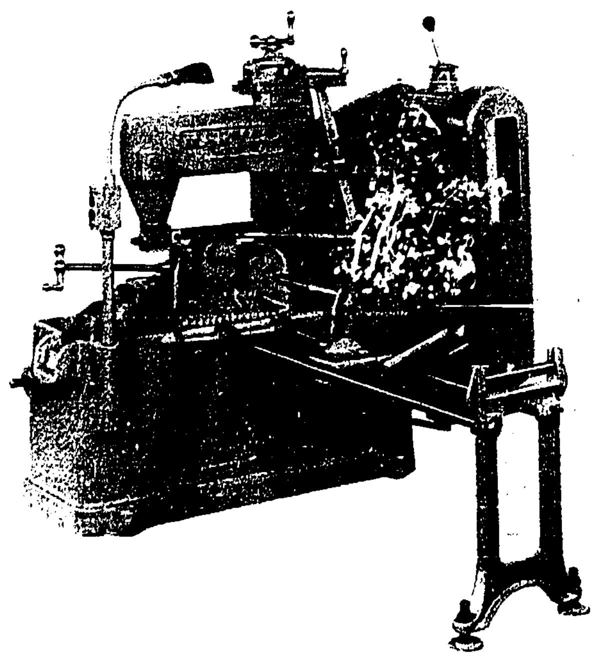
Make sure you exercise care in working with pneumatic pavement breakers or other types of pneumatic tools and accessories. Some general precautions to bear in mind are given below.

The operators of pneumatic tools should wear goggles to protect the eyes from chips and dust, and use the necessary personal protective devices.

Lay down pneumatic tools in such a manner that no harm can be done if the switch is accidentally tripped. Do not leave an idle tool in a standing position.

Shut off and exhaust pressure from the line before disconnecting the line from the tool.

The airhose must be suitable to withstand the pressure required for the tool. A leaking or defective hose must be removed from service. Hose should not be laid over ladders, steps, or sidewalks in such a manner as to create a tripping hazard. Where the hose is run through doorways, the hose should be protected against damage by the door edge. The hose should be laid between the operator's legs while he is using the pneumatic tool.



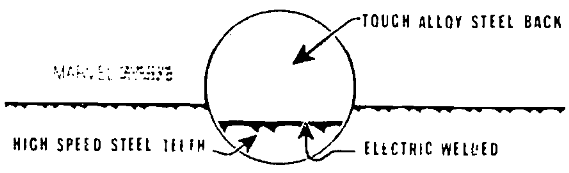
11.18X

Figure 4-8.—Power hacksaw.

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 4-8, 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. The capacity designation of this power hacksaw is 4" x 4", which means it can handle material up to 4 inches in width and 4 inches in height.

There are three types of feed mechanisms: mechanical, hydraulic, and gravity. Mechanical feed ranges from 0.001 to 0.025 inch per stroke,



11.19X
Figure 4-9.— Power hacksaw blade.

depending upon the class and type of material being cut. Hydraulic feed 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. In gravity feed, weights on the saw frame can be shifted to increase or decrease the pressure of the saw blade on the material being cut. With each type of feed mechanism, the blade lifts clear of the work during the return stroke.

Hacksaw Blades

The blade shown in figure 4-9 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.

Hacksaw blades vary in pitch, which is defined as the 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 for wide, heavy sections in order to provide ample chip clearance. For thinner sections, use a blade whose pitch 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 as indicated below.

Coarse (4 teeth per inch), for soft steel, cast iron, and bronze.

Regular (6 to 8 teeth per inch), for annealed high carbon steel and high speed steel.

Medium (10 teeth per inch), for solid brass stock, iron pipe, and heavy tubing.

Fine (14 teeth per inch), for thin tubing and sheet metals.

Speeds and Coolants

Speeds on hacksaws are stated in strokes per minute (spm). Count only those strokes which cause the blade to come in contact with the stock. Speed is usually changed by means of a gear shift lever. There may be a card attached to your equipment or near it, stating recommended speeds for cutting various metals. The following speeds, however, can usually be used in cutting the metals listed below.

136 spm — Cold rolled or machine steel, brass, and soft metals.

90 spm — Alloy steel, annealed tool steel, and cast iron.

60 spm — High speed steel, unannealed tool steel, and stainless steel.

Cast iron should be cut entirely dry, but a coolant should be used when all other materials are cut. 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.

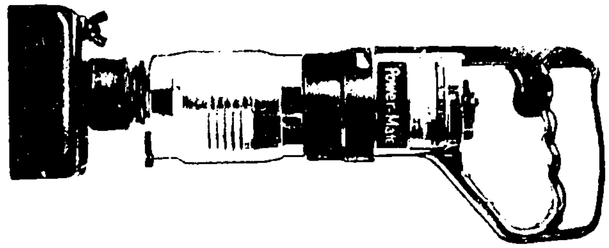
When you operate the power hacksaw, place the pipe in the clamping device, adjusting it so that the cutting off mark is in line with the blade. Next, turn the vise lever to clamp the pipe in place, being sure that the material is held tightly, and then set the stroke adjustment. Before you start the machine, check to 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.

POWER-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. 4-10) is a high-velocity device in which the fastener is shot down the barrel of the tool by a relatively powerful powder charge. Another ype (fig. 4-11) 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 4-10 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 figures 4-12 and 4-13 for the proper pins and studs.) The barrel on this type powder-actuated tool can be changed in a matter of seconds, so as to adapt the tool to either of the kits described in figures 4-14 and 4-15. This can be a difficult and dangerous tool to use, so be sure to study the manufacturer's manual beforehand.

The power-assisted stud driver shown in figure 4-11 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 figure 4-11, is seated, guided, and controlled in the recessed piston. The rimfire 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. Overpenetration is prevented by the positive control of the fastener exercised by the piston and guide disk. The hazards of 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.



133.78

Figure 4-10.—Power-Mate stud driver.

The power-assisted hammer-drive tool 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 4-16 shows a wood-to-metal connection; figure 4-17, a metal-to-concrete connection.

Figure 4-18 shows some of the other types of widely used pins and studs. The tool illustrated in figure 4-11 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.

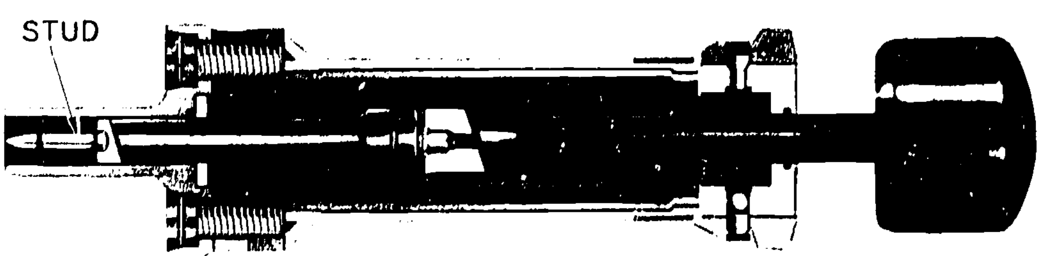


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Figure 4-11.—Cutaway view of power-assisted stud driver.

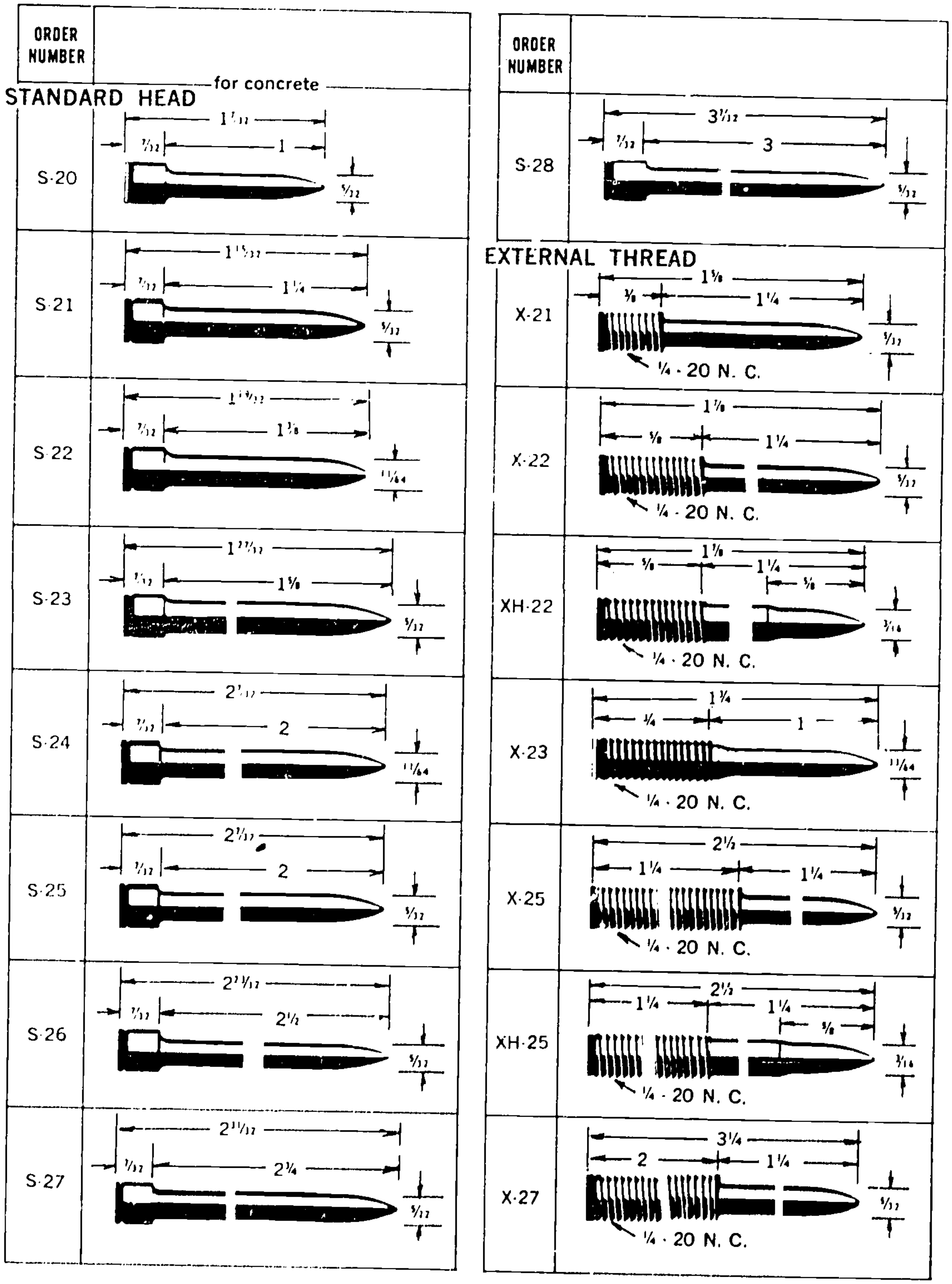

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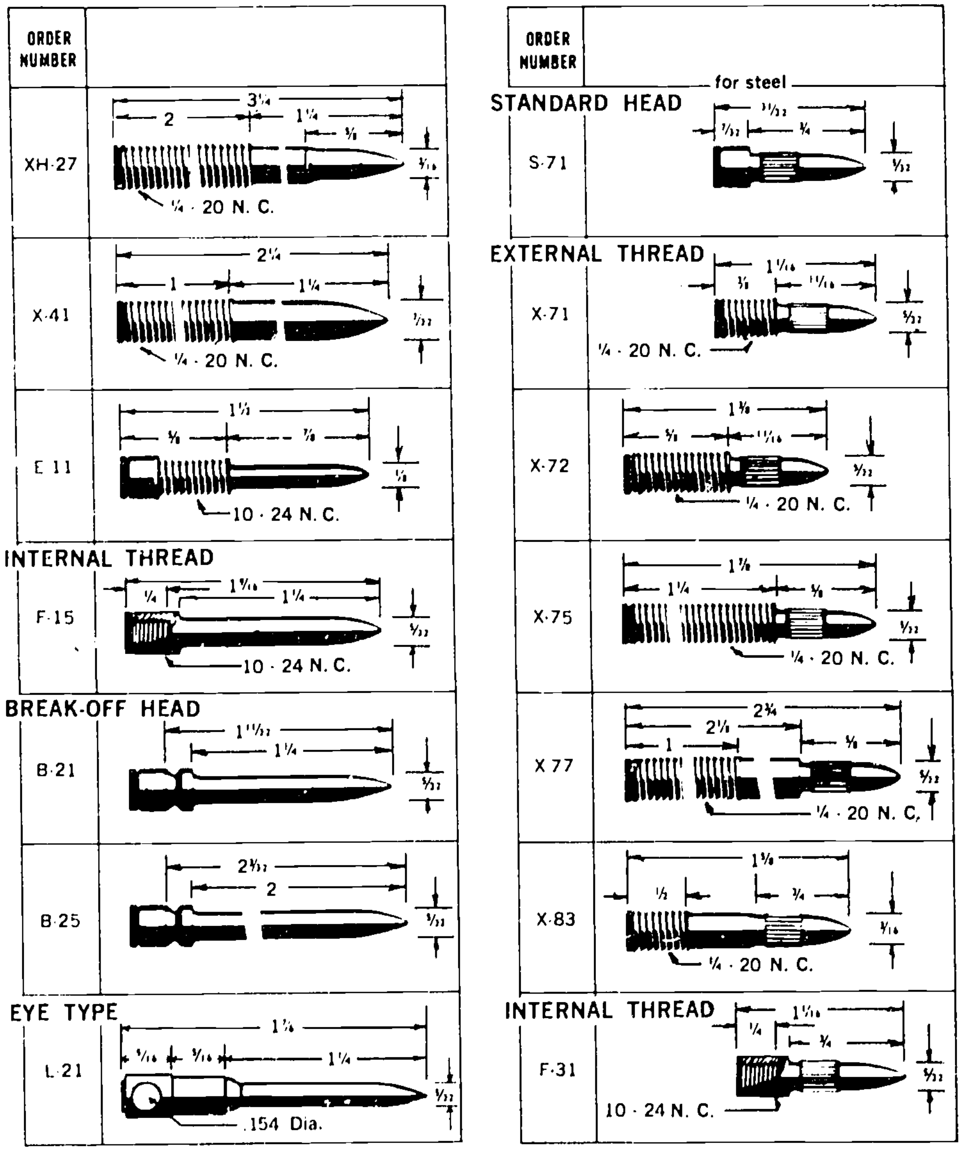
Figure 4-12.—1/4" headed pins and threaded studs.

29.121.2



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

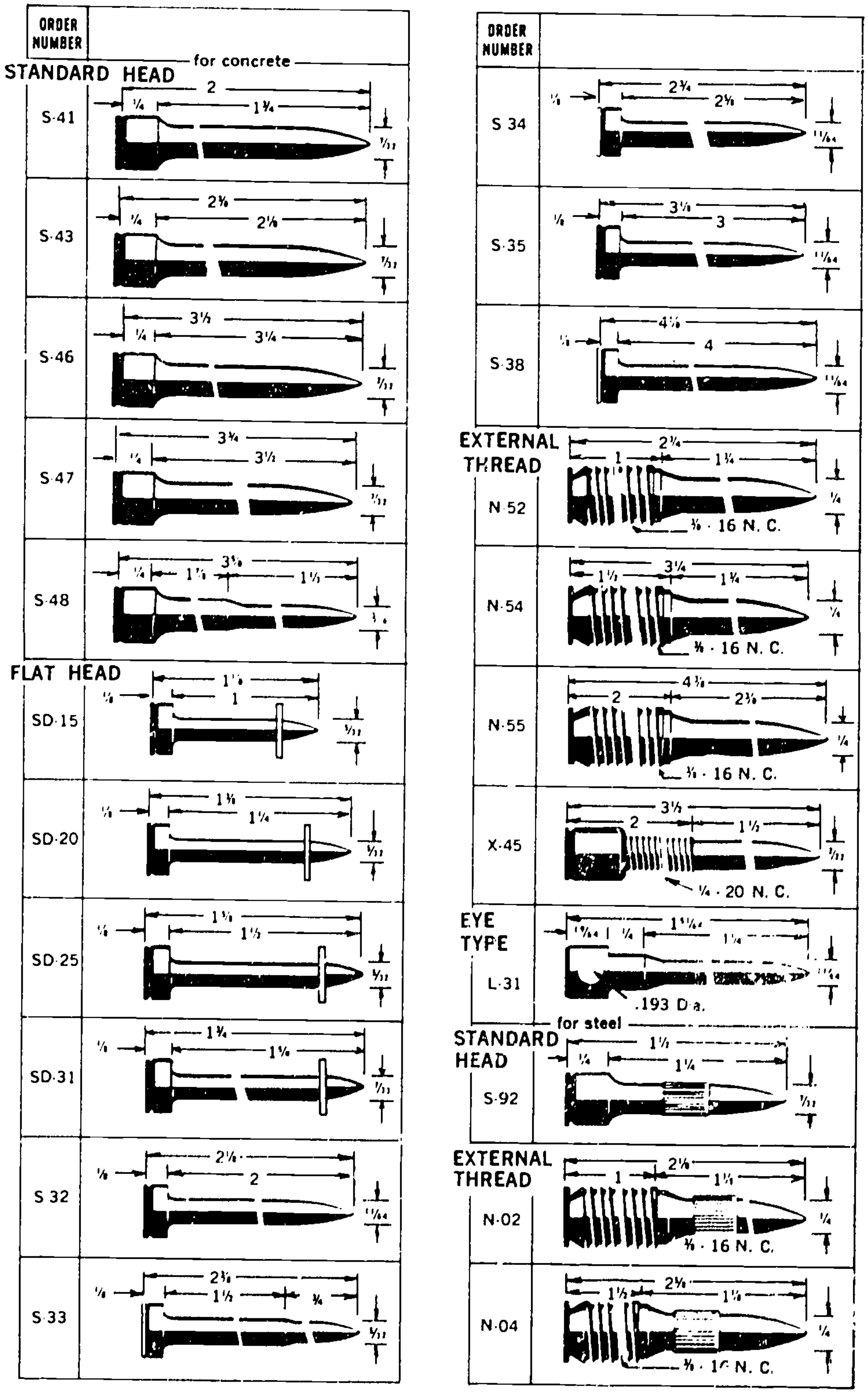
ORDER NUMBER	LOAD LEVEL NUMBER	HEAD COLOR
25c1	1	Gray
25c2	2	Brown
25c3	3	Green

32 CALIBER STANDARD—Wad

ORDER NUMBER	LOAD LEVEL NUMBER	WAD COLOR
32w8	8	Brown
32w9	9	Green
32w10	10	Yellow
32w11	11	Red

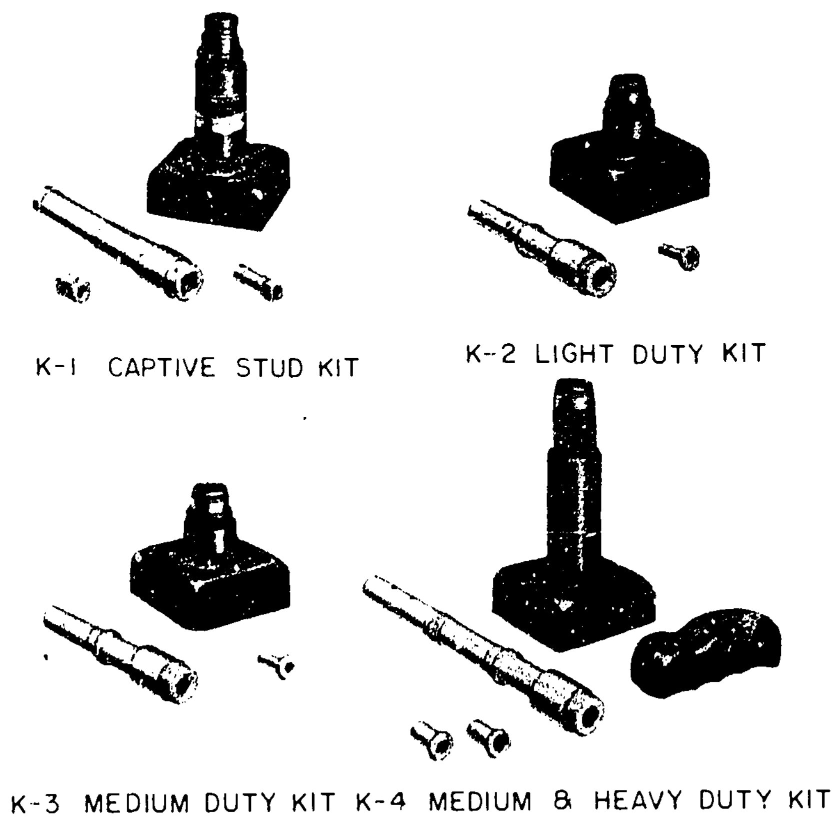
29.121.2

Figure 4-12.—1/4" headed pins and threaded studs—continued.



29.121.3

Figure 4-13.—3/8" headed pins and threaded studs.



133.340.1

Figure 4-14.—Stud driver kits.

However, if you have studs with two different thread lengths (such as shown in fig. 4-18), 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 if you have the special piston that is needed for the fastener.

Powder-actuated tools should be operated, repaired, serviced, and handled only by CE's 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.

AIR COMPRESSORS

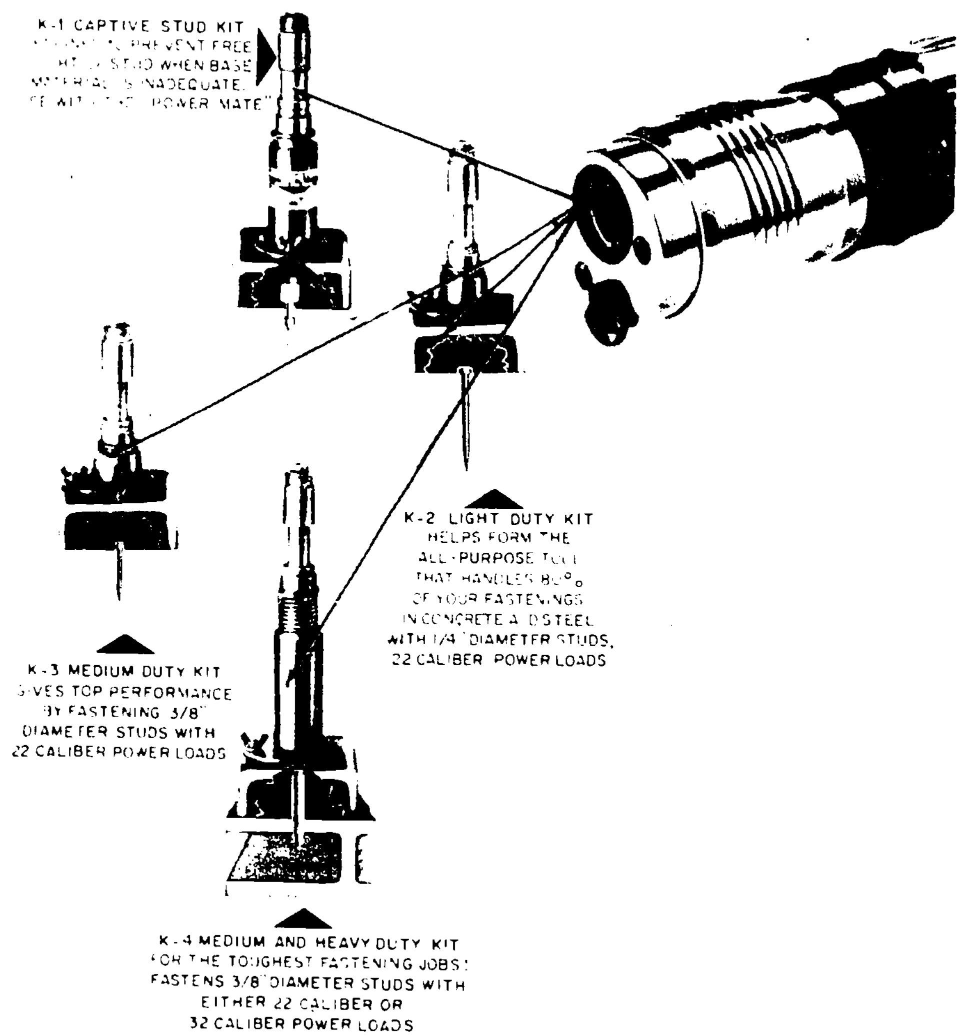
A compressor is a machine that increases the pressure of air by reducing its volume. A compressor consists of a driving unit, a compressor unit, and accessory equipment. The driving unit provides power to operate the compressor and may be a gasoline or diesel engine. Compressors are governed by a pressure control system adjusted to compress air to a maximum pressure of 100 pounds per square inch.

COMPRESSED AIR SYSTEM

A compressed air system consists of one or more compressors, each with the necessary power source, control of regulation, intake air filter, aftercooler, air receiver, and connecting piping, together with a distribution system to carry the air to points of use.

The object of installing a compressed air system is to provide sufficient air at the work area at pressures adequate for efficient operation of pneumatic tools being used.

Many construction jobs require more cubic feet of air per minute than any one compressor will produce. Terrain conditions often create problems of distance from compressor to operating tool. Since the air line hose issued with the compressor causes considerable line loss at distances further than 200 feet, a system has been devised for efficient transmission of compressed air over longer distances. This system is air manifolding (fig. 4-19). An air manifold is a large diameter pipe used to transport compressed air from one or more compressors over a distance with a small friction line loss. In construction work, air manifolds are usually constructed of 6-inch diameter pipe. A pipe of this size can carry 1200 cubic feet per minute of air (output from two 600 cfm air compressors) at 100 pounds per square inch with less than .035 pound pressure loss per 100 lineal feet. One or more compressors pump air into the manifold and eventually pressurize it at 100 pounds per square inch; then air may be used



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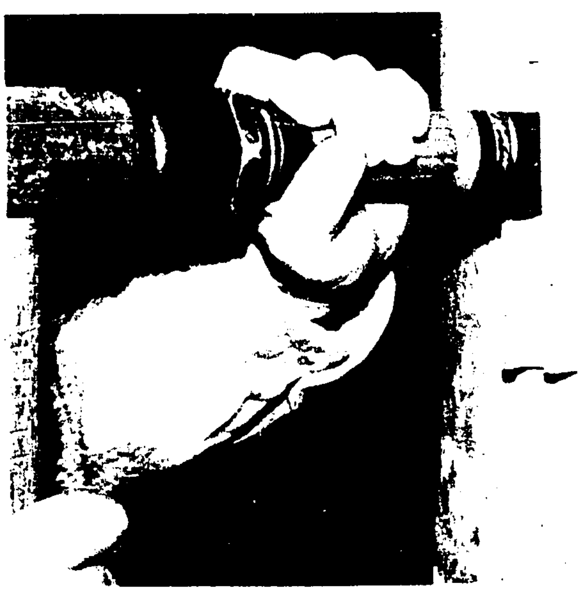
133.340.2

Figure 4-15.— Purpose of individual stud driver kits.

133.79X
Figure 4-16.—Toenailing wood to hollow metal decking.



133.81X
Figure 4-17.—Fastening channel to concrete.

at any point along the manifold by installing outlet valves and connecting air lines and pneumatic tools.

COMPRESSOR OPERATION AND MAINTENANCE

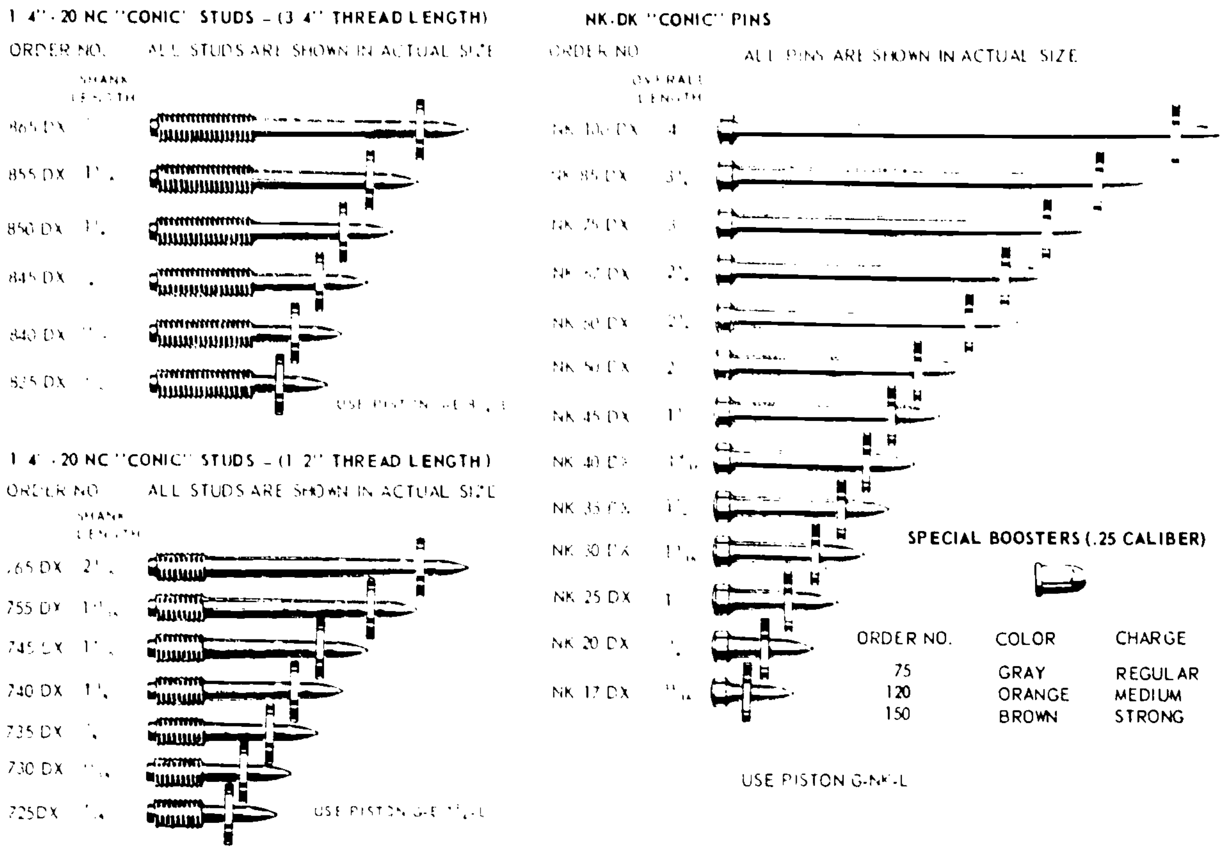
The following paragraphs will give general instructions on operating and maintaining air compressor units. One of several types that SEABEES operate and maintain is the Worthington 600-cfm portable compressor (fig. 4-20) which is diesel-engine driven. The complete unit is equipped with springs, tires, and a drawbar. The drawbar is normally located on the compressor end of the chassis. When the unit is coupled to a self-propelled crawler drill supplying air for its tramming motors, this drawbar location keeps the radiator and oil cooler further away from the cloud of dust which the crawler rig can create.

The compressor unit must be located on a reasonably level area. The design of this unit permits a 15-degree lengthwise and a 15-degree sidewise limit on out-of-level operation. The limits are placed on the engine, not the compressor. When the unit is to be operated out-of-level, it is important: (1) to keep the engine crankcase oil level near the high level mark (with the unit level), and (2) to have the compressor oil gage show nearly full (with the unit on the level).

An instruction plate similar to the one shown in figure 4-21 is attached to the unit. Notice that this plate refers you to the manufacturer's engine and compressor manuals for detailed instructions.

Operating the Clutch

The clutch should remain engaged at all times except during engine warmup or tuneup periods. In this way its compression springs and shifter mechanism are not under a constant strain. The compression springs hold the friction disks in the engaged position; the shifter mechanism forces the disks apart hydraulically against the spring compression to disengage the clutch. A built-in safety interlock prevents the clutch



29.121X

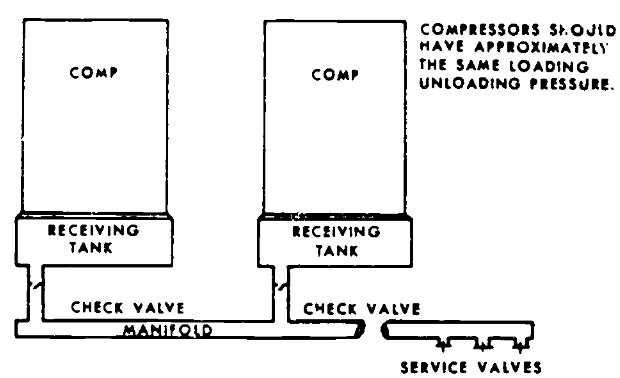
Figure 4-18.—Studs and pins.

from being engaged or disengaged while the engine is running.

When the engine is stopped, the clutch sleeve can be pushed down easily to expose a knurled knob which is turned to engage and disengage the engine clutch. Never try to move the clutch sleeve and turn the knob when the engine is running. Always shut down the engine before engaging or disengaging the clutch.

To disengage the clutch, turn the knob clockwise as far as it will go. Pressurize the clutch shifter by stroking the hydraulic pump handle. A built-in pressure relief valve prevents overpressurizing.

To engage the clutch, turn the knurled knob counterclockwise three or four turns until the pump handle offers little resistance to pumping. Leave the knob in this position.



115.385

Figure 4-19.—Methods of manifolding compressors.

Starting the Unit

The following steps should be taken when starting the engine during mild or warm weather:

1. Open service valves about one quarter — not wide open.

> NOTE: The reason for starting with the service valves partly open is that they aid in quicker warmup of the compressor oil.

2. Make sure the clutch is in engaged position.

3. Position the low-pressure, engine-oil-system safety-control-knob to ON (fig. 4-22).

4. Turn the ignition switch to start position. Immediately after the engine starts, release the ignition switch. If the engine fails to fire within 30 seconds, release the ignition switch and allow the starting motor to cool off for a few moments before trying the starter again.

5. With the engine running, check the engine oil pressure gage. If no pressure is indicated, turn the engine off. When the oil pressure goes above 22 psi, continue to operate the engine and check the low-pressure engine oil switch. The knob on this switch should be in the RUN position.

> NOTE: The engine oil pressure gage indicates erratically until the engine oil warms up.

6. Open the side curtains on both sides of the engine enclosure and leave them open. Flow of air through the oil cooler and engine radiator will be impeded if the side curtains are closed while the engine is running.

7. After the engine has run about 3 minutes, check the engine coolant temperature gage. The gage should indicate less than 210° F. If the gage is showing more than 210° F, SHUT OFF THE ENGINE.

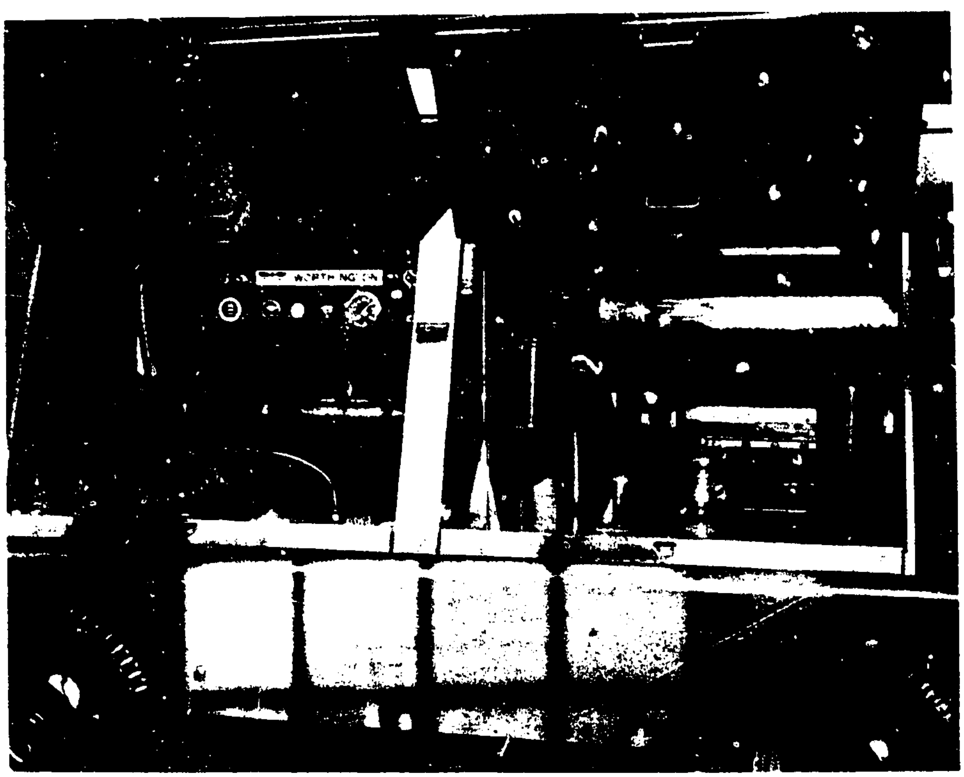


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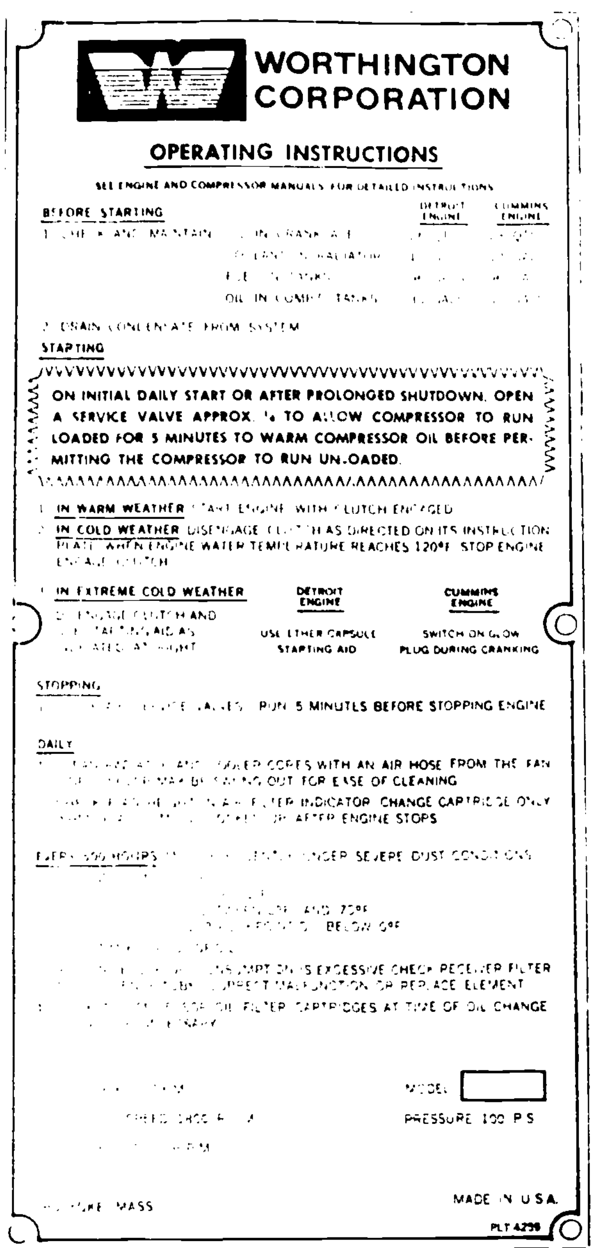
Figure 4-20.—Worthington 600 cfm portable, rotary air compressor.



115.378X
Figure 4-21.—Operating instruction plate.

8. After 5 minutes of operation, close the service valve and attach the hose or service line of the tool or device to be operated.

9. Open the service valves fully and start the work. After startup, the unit automatically provides compressed air at the discharge service valves. Only periodic checking of the gages on the instrument panel is then required.

10. When the engine is started during the day, after the first daily startup, the above warmup steps may be eliminated.

Stopping the Unit

When stopping the unit at the end of the day's run, take the following steps:

1. Close the service valves and permit the engine to run at idle for 5 minutes. This will allow the engine coolant temperature to level off and the entire unit to cool down.

2. Turn the ignition switch to the OFF position.

Cold Weather Starting

The following steps should be completed during cold weather starting:

1. Disengage the clutch. This will permit engine warmup at idling speed.

2. Start the engine using the heater switch and priming pump in accordance with the engine manual.

3. Warm the engine until the engine coolant temperature reaches 120° F. Leaving the side curtains closed for a few minutes helps the engine to warm up.

4. Turn the ignition switch to OFF.

5. When the engine has stopped, engage the clutch and start the engine again with the service valves partly open. Be sure the side curtains are open.

6. When the compressor has run for several minutes and the gages indicate normal operating conditions, connect up the tools and go to work.

87

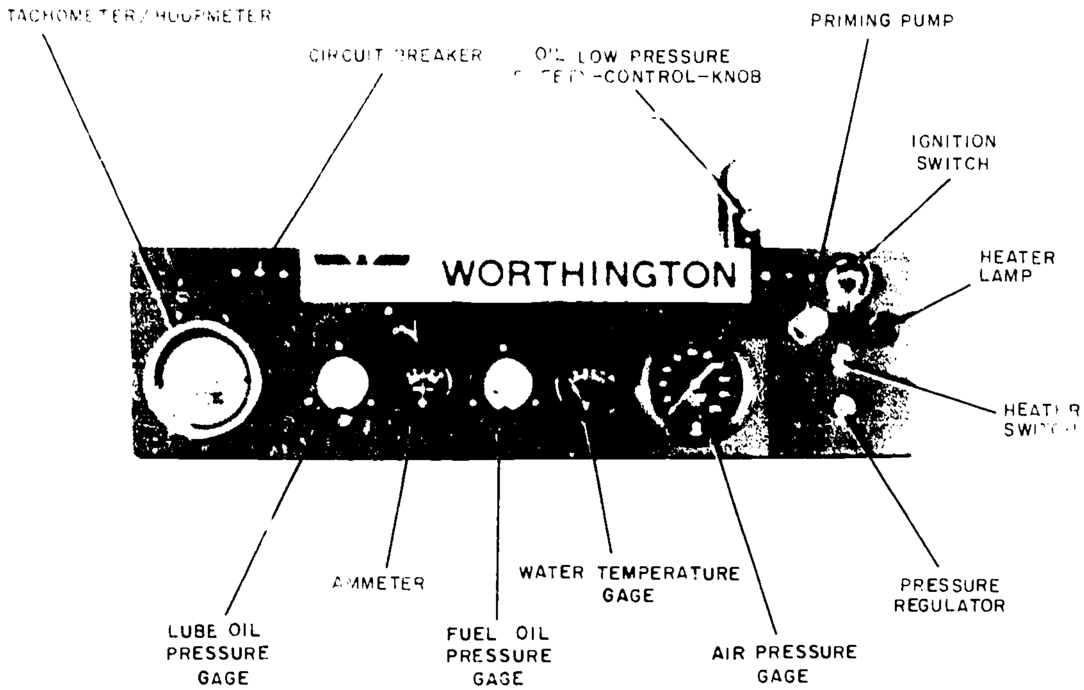


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Figure 4-22.—Instrument panel.

Lubricating the Unit

The lubrication chart in the operator's manual for the particular make and model of compressor you are operating will show you where the unit should be lubricated, how often to lubricate, and what lubricant to use. The frequency will vary depending upon operating conditions. Operating under abnormal conditions requires more frequent service.

CAUTION: Before servicing the compressor air system or compressor oil system, open the service valves to the atmosphere to relieve all pressure in the systems.

Servicing the Air Cleaner

A two-stage, dry-type air cleaner, installed inside the engine enclosure at the right rear, filters the intake air (fig. 4-23). Air is drawn into a first-stage element which causes nearly all the dust in the air to drop into a bin. Air then enters the second-stage element, a paper cartridge, where more dust is trapped and collected.

The dust bin should be removed by hand and emptied daily. Some models have a self-emptying dust bin that is piped into an aspirator in the exhaust pipeline, just beyond the muffler. When the aspirator is used, no alterations are allowed to be made to the engine muffler or exhaust pipe.

On the side of the air cleaner housing, there is mounted a service indicator. As the paper cartridge loads up with dust, a red indicator flag gradually rises in the window. When the cartridge is completely loaded, the window will show all red, and the flag will be locked in place. It is time to replace the paper cartridge. Discard the old cartridge and reset the red flag so that the window shows clear. Cleaning used paper cartridges is not recommended.

Drainage

Drain cocks are provided at the bottom of the compressor suction control and the engine speed control. These cocks should be left open when the unit is standing idle, particularly in freezing weather. They must be closed before the engine is started.

Drain any condensate which may have accumulated in the bottom of the oil storage tanks. A drain cock is provided on the piping at the bottom of the left hand oil storage tank. Open this cock and keep it open as long as water is draining out. Close the cock quickly when oil starts draining.

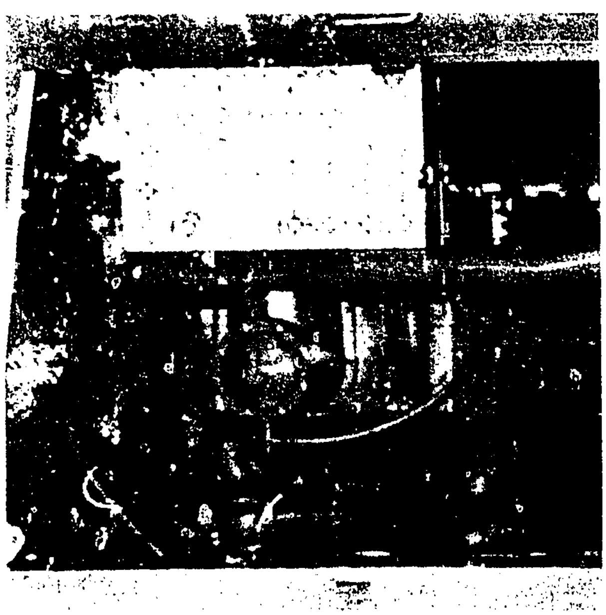
AIR COMPRESSOR SAFETY

General safety precautions for air compressors are as follows:

Be sure the air at intake is cool and free from flammable gases or vapors.

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 4[illegible] F.



115.379X
Figure 4-23.—Air cleaner.

Never disable pressure gages except when they are to be removed for good reason.

Never kink a hose to stop the air flow. Keep the clamps on the hose tight.

When starting an air compressor, check the safety valves, pressure valves, and regulators to determine that they are working properly.

Do not leave the compressor after starting it unless you have 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.

Use only the proper grade of oil recommended by the manufacturer, and avoid the application of too much oil. Use only oils which have high flashpoints to lubricate the air cylinders of air compressors.

Keep compressors, tanks, and accompanying piping clean to guard against oil vapor explosion. Clean intake air filters periodically.

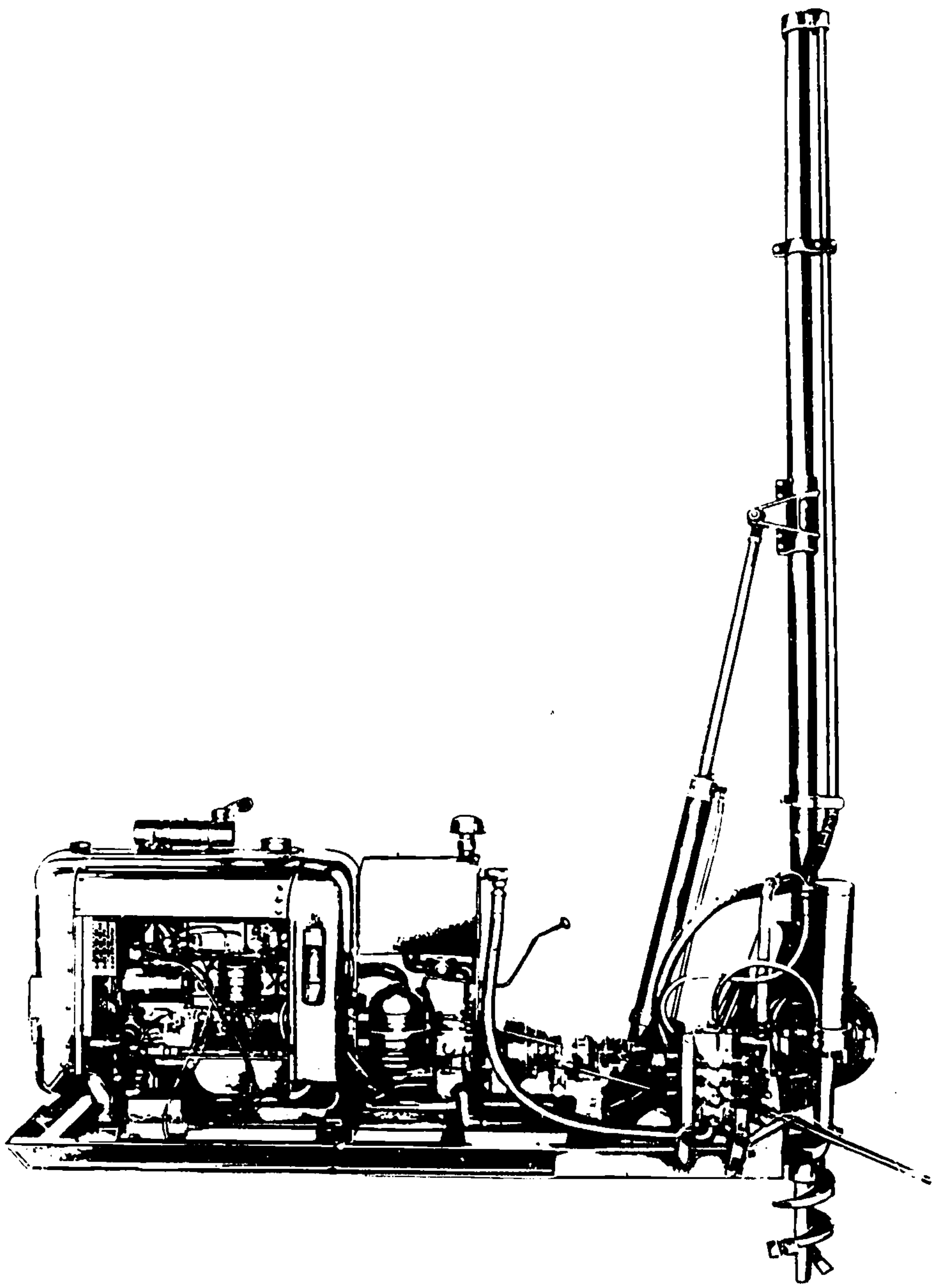
Use only soapy water or suitable nontoxic, nonflammable solution for cleaning compressor intake filters, cylinders, or air passages. Never use benzene, kerosene, or other light oils to clean these parts. These oils vaporize easily and will form a highly explosive mixture under compression.

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.

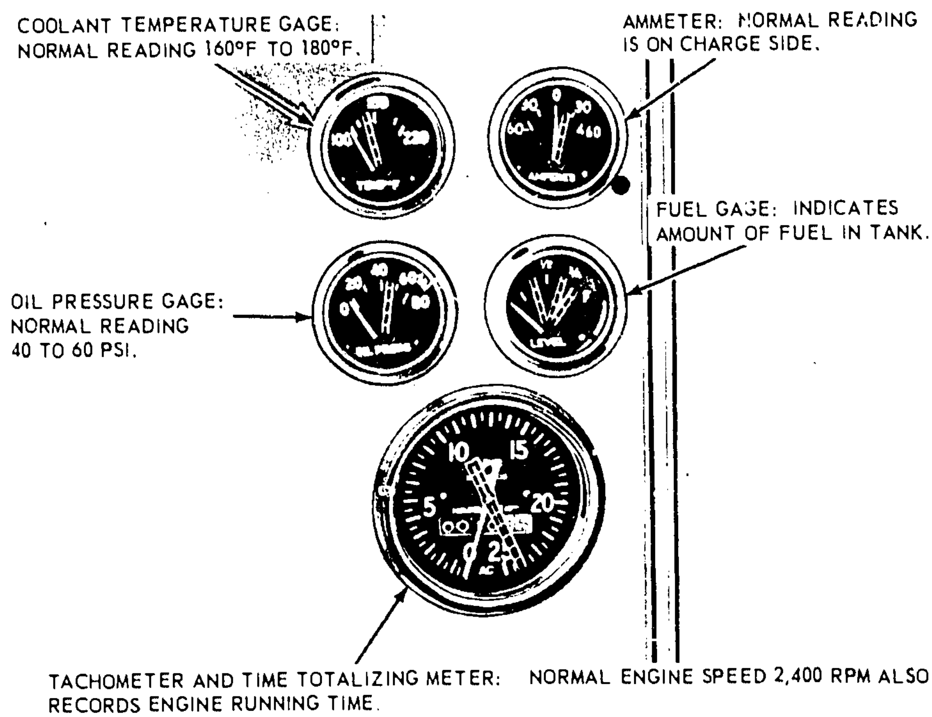
POWER EARTH AUGERS

An earth auger is used to dig holes for placing posts, poles, and explosives charges. It is also used to remove soils for testing. Among other things, the earth auger is very useful in subsurface soil explorations for boring holes up to 20 inches in diameter and up to 9 feet in depth. The power earth auger (fig. 4-24) is a self-contained, hydraulically operated and positioned earth boring machine. The boring assembly can be operated from vertically downward to 45 degrees from vertical. The power earth auger is normally



115.484

Figure 4-24.—Power earth auger.



115.485

Figure 4-25.—Instruments, power earth auger.

mounted on the bed of a truck to increase down pressure and aid in transporting.

The auger, at full speed in fourth gear, will rotate at less than 150 rpm, or in low gear at not more than 40 rpm. The auger hydraulic valve levers are placed so that you can observe the boring operations and the engine instruments at the same time.

The earth auger is usually driven by a gasoline engine. The auger assembly consists of the auger, kelly bar, final drive assembly, and right-angle drive assembly. Operation of the boring assembly is controlled by the auger clutch which engages or disengages the kelly bar.

OPERATION OF POWER EARTH AUGERS

To give you some idea as to the operation of a power earth auger, information is given below on the Texoma Enterprise's earth auger, Jaques model TJ 254. Figures 4-25 and 4-26 show the instruments and controls of this earth auger. Bear in mind that the procedure of operation may vary from one earth auger to another, so make it a practice to check the manufacturer's manual for the recommended procedure for the auger to be used.

Starting the Auger Engine

There are certain steps you must take in starting the auger. After performing the routine prestart checks of the engine crankcase oil level, transmission oil level, fuel supply, battery water level, coolant level, and hydraulic oil level, be sure that the proper amount of lubricant, water, and electrolyte is added, as required, to bring the specific unit to the proper level or full mark. Place all controls in neutral position and then open the fuel shutoff valve and the hydraulic oil shutoff valve. By following the step-by-step procedures given in figure 4-27, you should have no difficulty starting the auger engine.

Steps for Auger Operation

Follow the procedures below to place the power earth auger in motion after the engine has been started:

1. Disengage the engine clutch and shift the transmission into fourth gear.

2. Engage the engine clutch and run the engine at idle speed.

3. Pull the elevating valve lever to elevate the auger shaft into the vertical position and plumb as indicated by the elevating spirit level.

4. Engage the auger clutch by pressing down on the auger clutch shift lever and allow the auger shaft to rotate for 5 minutes.

NOTE: Do not run the engine faster than idle until the auger gears are thoroughly warmed up.

5. After the auger has been warmed up, disengage the auger clutch.

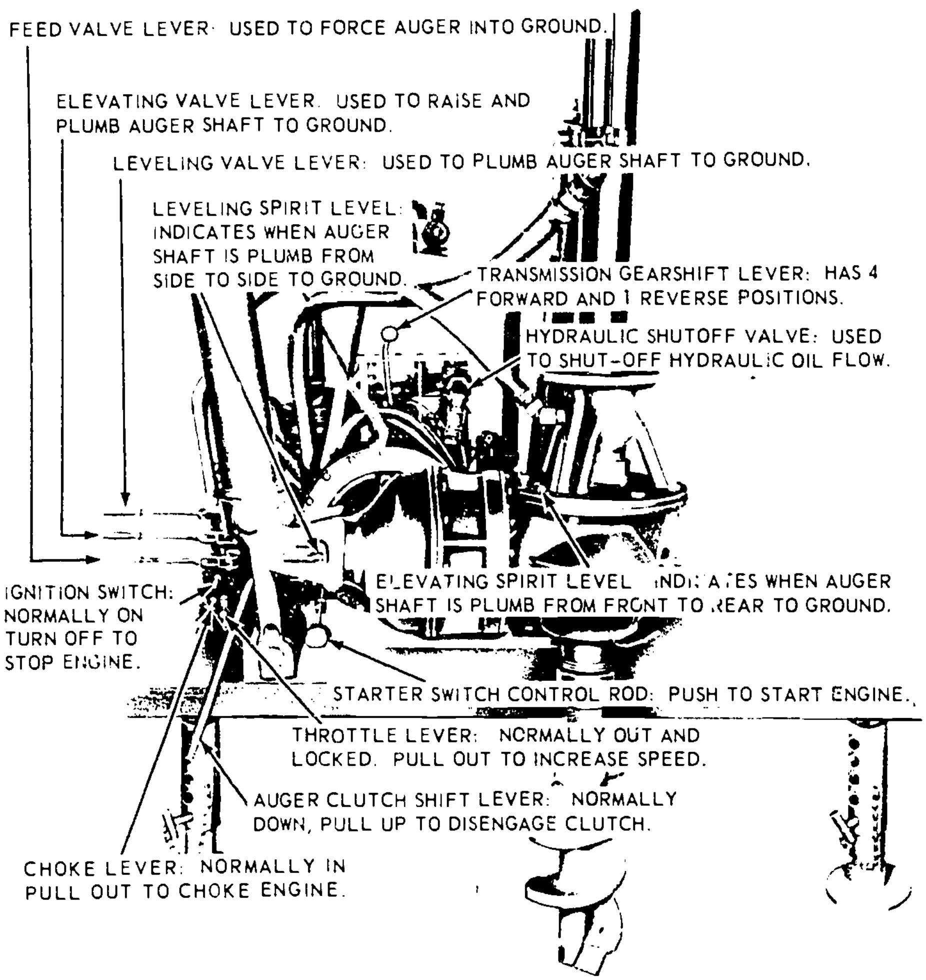


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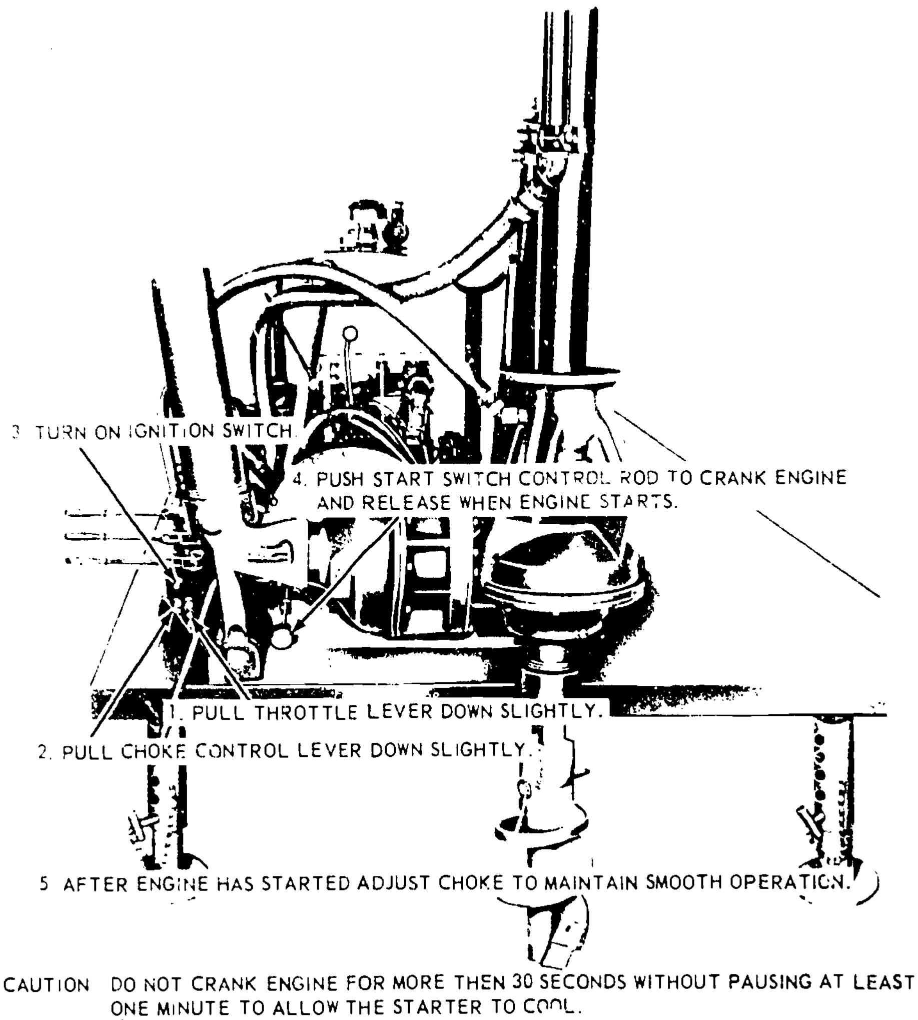
Figure 4-26.—Controls, power earth auger.



115.487

Figure 4-27.—Starting the auger engine.

Stopping the Auger Engine

To stop the auger engine, observe the steps given in figure 4-28 after disengaging the engine clutch and shifting the transmission into neutral.

OPERATING TECHNIQUES

Under ordinary circumstances an auger will be operated as described below. Figure 4-29 shows the auger controls and how to position the auger with these controls. With the LEVELING VALVE LEVER, the auger shaft can be tilted to the right or left as indicated in view A. With the ELEVATING VALVE LEVER, the auger shaft can be raised or lowered for transporting, as shown in view B of the illustration. The LEVELING SPIRIT LEVEL is used to plumb the auger shaft.

After the auger shaft has been placed in the desired drilling position you are ready to begin drilling operations. This is done by engaging the auger CLUTCH LEVER, pulling back on the THROTTLE LEVER to increase engine speed, and then pushing forward on the FEED VALVE LEVER to lower the auger into the ground as shown in view C, figure 4-29.

CAUTION: Do not overspeed the auger. Run the engine at slow speed until the texture of the material can be determined.

When the auger is deep enough in the ground to be loaded with dirt, disengage the auger CLUTCH LEVER and pull back on the FEED VALVE LEVER to raise the auger from the hole. After the auger has cleared the hole, engage the auger CLUTCH LEVER (fig. 4-29) to rotate the auger and to clear the unit of dirt. Remember, as you raise the auger, push the hand THROTTLE forward to lower engine speed.

Repeat the steps above until the hole being drilled is at the desired depth.

SECURING A TRUCK-MOUNTED POWER EARTH AUGER

When mounted on a truck for portable use, a power earth auger should be secured in the following manner: Position the auger for traveling and stop the auger engine. Be sure to close the fuel shutoff valve and the hydraulic oil shutoff valve. Drive the truck to the designated securing area, and position the auger in a safe manner. After the truck has stopped, disengage the engine clutch, put the main transmission shaft lever in neutral, engage the truck parking brake, and turn the ignition off. Secure all doors and windows before leaving the truck.

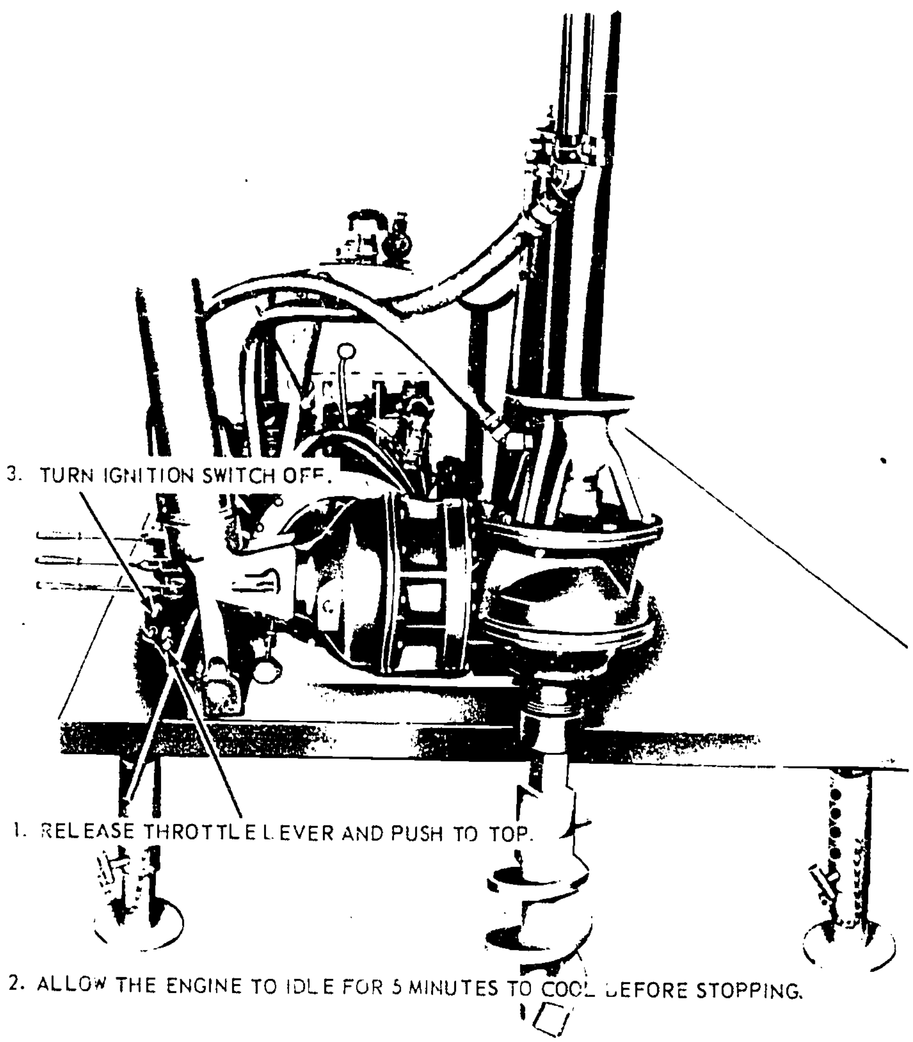


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Figure 4-28.—Stopping the auger engine.

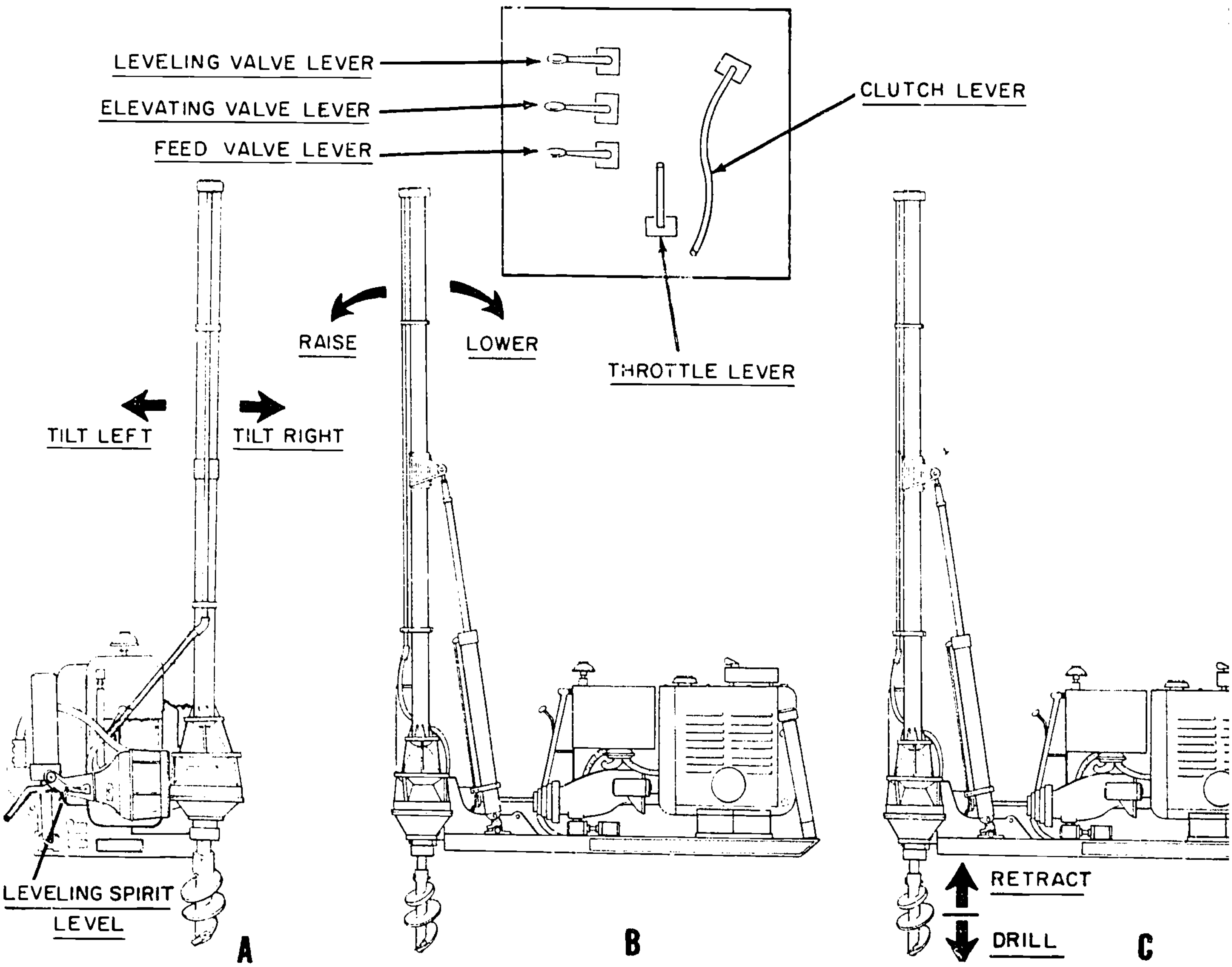
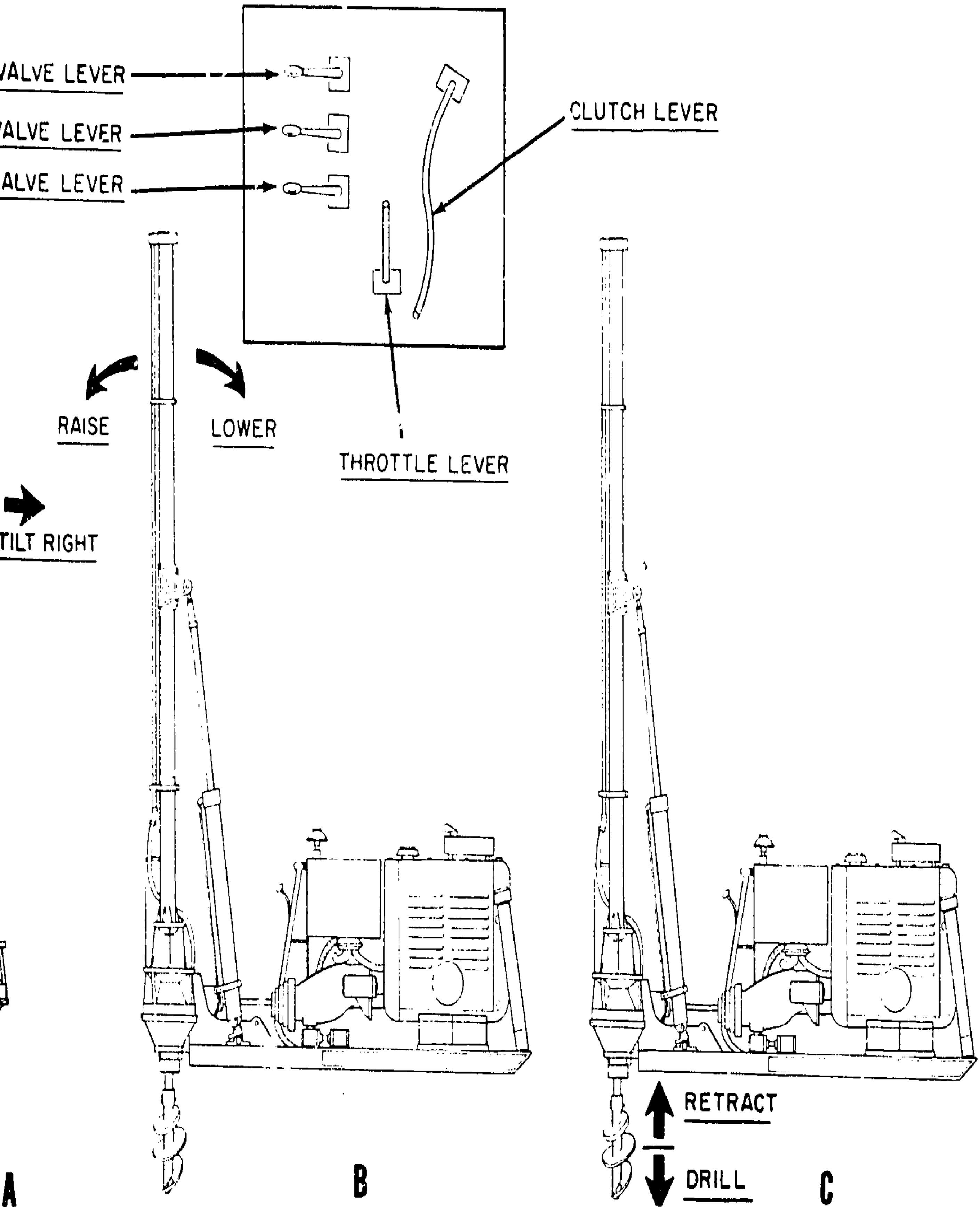


Figure 4-29.—Using auger controls for positioning of auger.



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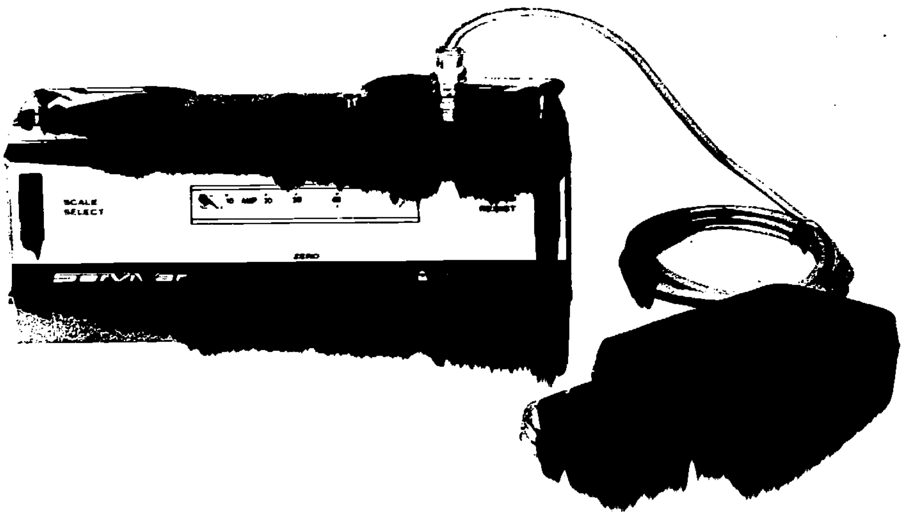
gure 4-29.—Using auger controls for positioning of auger.



26,230X

Figure 5-23.—Servivar electrical tester.

:olor coded so that the user can quickly
nize whether he is on the a-c current
, a-c volt scale, or the ohm scale.

ecial circuitry (not shown) prevents damage
e meter when voltage is applied inadvert-
to the instrument when it is on the ohm
. This is accomplished without the use

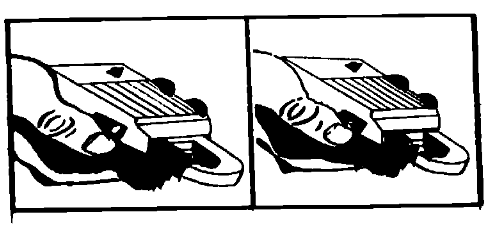


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Figure 5-24.—Snap-around probe.

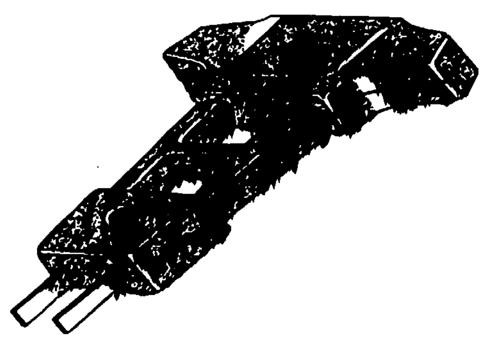

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Figure 5-25.—Line splitter.

CHAPTER 5

TEST EQUIPMENT

As a Construction Electrician, you will be required to place new electrical equipment into operation, repair defective equipment, and perform routine preventive maintenance. To help you accomplish these jobs, many types of test equipment are available. Some of these may appear to be complex. When analyzed, however, their theories and techniques of operation may be reduced to simple basic circuits and procedures. Electrical theory underlying the operation of some basic test instruments is covered in detail in chapter 15 of Basic Electricity, NAVPERS 10086-B. A good grasp of this material will help you to understand not only how the instruments are designed to work, but also the importance of applying theoretical analysis to problem solving.

This chapter describes test procedures and equipment used for investigating a variety of difficulties. You should be able to repair vital equipment when you follow correct test procedures and the manufacturer's instructions.

The purpose of these instruments is to test and measure accurately certain circuit values or to determine the operating condition of the electrical circuits. Instrument accuracy depends on its design and how it is treated.

The operating energies involved in electrical measuring instruments are extremely small. The instruments themselves are necessarily of delicate construction. Special precautions must be taken to obtain accurate results and to avoid injury to the operator by mechanical shock, exposure to strong magnetic fields, and excessive flow. One of your major responsibilities is to take care of any instruments assigned to you. Instructions and wiring diagrams are furnished with instruments. Such instructions are either attached to the instrument case or cover, or are given in separate instruction books. These should be consulted freely for specific instructions and precautions.

BASIC MEASURING INSTRUMENT PRECAUTIONS

When using measuring instruments, you must observe certain precautions. For example, it is especially important to be careful in using an ammeter because of its low internal resistance. If mistakenly placed across a voltage source, the meter can be damaged. Always break the circuit and CONNECT AN AMMETER IN SERIES, with one meter lead going to each point of the circuit break to measure an unknown quantity. Be sure to deenergize the circuit before making or breaking the connections.

When using either ammeters or voltmeters, ALWAYS start at the HIGHEST meter range. Then drop down to a lower scale range if necessary. This practice protects the meter from injury if an attempt is made to read a high value in a low range. Damage to instruments can also be minimized if you form the habit of placing the range selector switch in the highest range position after you have finished using the instrument.

OBSERVE POLARITY on all direct current measurements. Take care to connect the positive terminal of the source to the positive terminal of the meter, and the negative terminal of the source to the negative terminal of the meter. This ensures that the meter polarity matches the polarity of the circuit in which the meter is placed.

Be careful to avoid dropping a meter or subjecting it to excessive mechanical shock. Such treatment may damage the delicate mechanism or cause the permanent magnet to lose some of its magnetism.

Care must be taken to avoid connecting the ohmmeter across circuits in which a voltage exists, since such connection can result in damage to the instrument. TO ENSURE THE REMOVAL OF ALL VOLTAGE TO THE EQUIPMENT UNDER TEST, DISCONNECT THE SOURCE OF INPUT VOLTAGE BY REMOVING

THE POWER PLUG. Furthermore, ALL CAPACITORS MUST BE DISCHARGED before the ohmmeter prods are connected in the circuit. Charges remaining on capacitors after the applied voltage has been removed can damage the instrument severely.

Always turn ohmmeters OFF when finished. This will avoid discharge of the internal battery if the test leads are shorted inadvertently.

It is important that you remember to USE A LOW VOLTAGE MEGGER TO TEST LOW VOLTAGE INSULATION. Application of high voltage may initiate insulation breakdown. LOW VOLTAGE MEGGERS should not be used to test high voltage insulation because an inaccurate reading may result from the comparatively small output voltages available from this instrument. Be careful, whether using high or low range meggers. Dangerous voltages exist at meter terminals and leads.

BASIC TEST EQUIPMENT

As a CE, you will use various types of test equipment. Some of the basic types of test equipment with which you should be familiar are described in the following paragraphs.

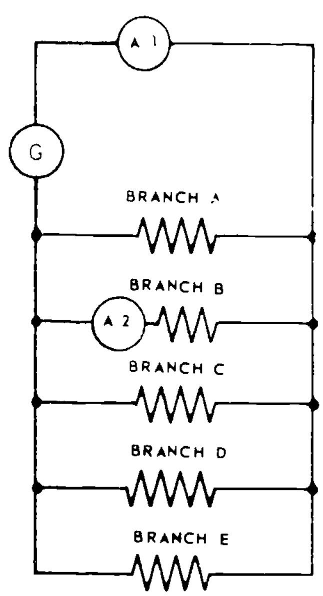

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Figure 5-1.— Metering current in an entire cir-

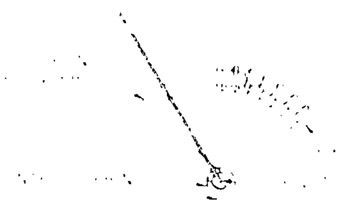

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Figure 5-2. Schematic of a magnetic-vane attraction-type ammeter.

AMMETERS

You can use an ammeter to measure total current through a circuit, or you can use it to measure current through only a part of the circuit. Figure 5-1 illustrates both methods of measurement. In the figure the symbol A1 indicates an ammeter which is measuring the total current through branch circuits A, B, C, D, and E. The symbol A2 indicates an ammeter which is measuring the current through branch circuit B only.

Because the function of an ammeter is to measure current, it must always be connected in series with the line, and with the load on the line. It must never be subjected to a current higher than the rating on the meter.

In the type of ammeter used at advanced bases, the coil through which the measuring current flows is fixed to the instrument frame. The magnet is a movable vane of iron or of special alloy, as indicated in figure 5-2. Magnetism induced in the iron by the current in the field coil always has the same polarity as that of the coil, when alternating current flows in the coil. Therefore, when the current reverses in the coil, the polarity of the magnetism induced in the moving iron also reverses.

The instrument is calibrated in amperes, and rated according to its maximum current-carrying capacity. Because of the fixed relationship in polarity between field flux and moving vane flux, the instrument could be calibrated for either alternating or direct current. In the latter case, however, the meter could not indicate the polarity of the current.

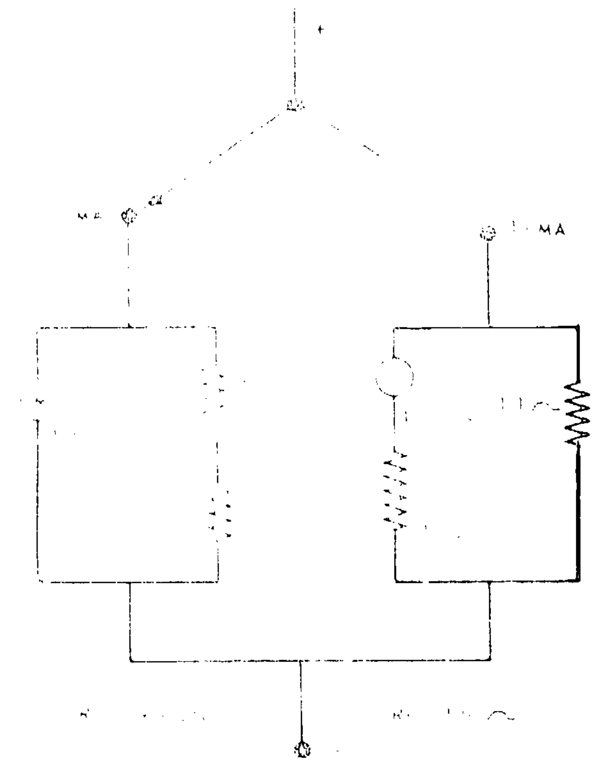
The field coil must supply all the energy necessary to operate the meter movement. Any meter of a given rating, operating on the moving-vane principle, requires more power than a moving-coil meter of the same rating. The

... through a

... the size of the meter ... switch with the ... very high ... large for the

... current that can ... meters are ... (fig. 5-3) ... current up to ... meters are

... of an ammeter ... instruments are ... ranges, depending ... current that is being ... figure 5-4 are



73.40

Figure 5-4. Triple-shunt ammeter.

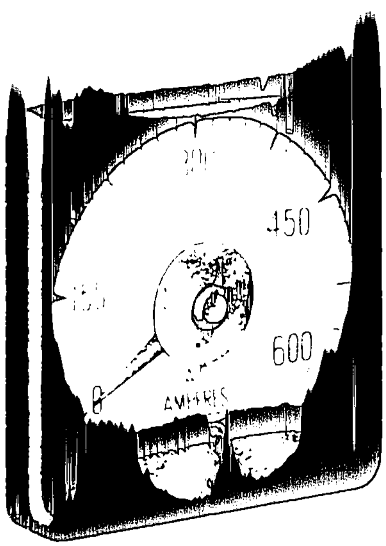


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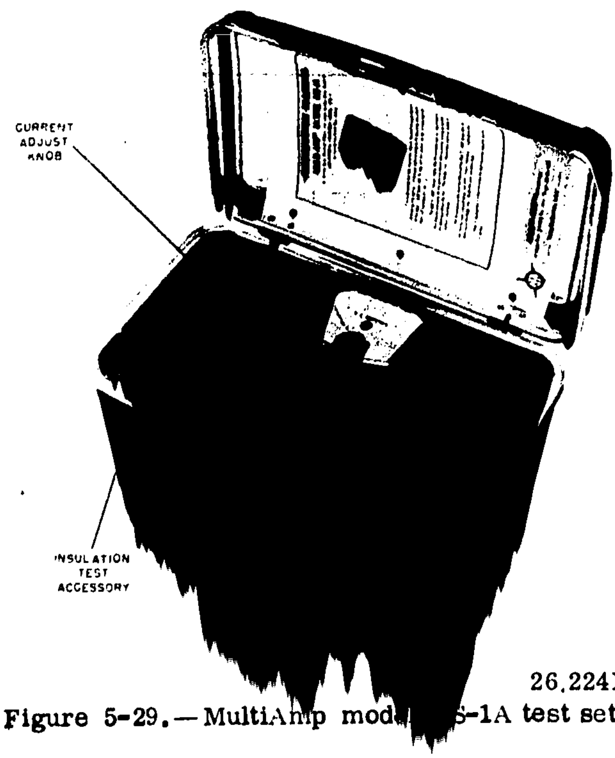
Figure 5-3. Typical switchboard ammeter.

internal — that is, installed inside the meter case. They are fixed shunts, meaning that when the meter is installed in a circuit, the shunts become part of the circuit.

External shunts are installed on the outside of a meter case, or on the back of a switchboard. They can be changed for the purpose of increasing the range of the meter. Although you are not supposed to make adjustments on meters, there may be an occasion when you have no instrument available that suits your special need, and will have to improvise from what is at hand.

The shunting method about to be described is not really satisfactory for ammeters operating on the fixed-coil moving-vane principle. A shunt is entirely satisfactory on a moving-coil instrument, to extend the range upward. A moving-iron element, however, is much less sensitive than a moving coil, and would require a greater voltage drop across the shunt.

Greater voltage drop causes greater heating in the shunt. Greater heating must be off



26.224X

Figure 5-29.—MultiAmp model MS-1A test set.

An accessory to the MS-1A tester, used for insulation measurements, fits into the accessory socket in the test lead compartment (fig. 5-29). With it, insulation measurements from 2 to 1000 megohms with ±5 percent accuracy can be made.

MODEL [illegible] VIBROGROUND

Electrical systems and specific electrical equipment must be protected from damage or destruction by voltages from other circuits, or lightning. Manmade grounds provide this safety feature. To provide maximum protection, these grounds must be checked regularly.

Figure 5-30 shows the Vibroground, an instrument specifically designed to check grounds quickly and accurately.

The Vibroground works on a null-balance principle. The basic circuit is indicated in figure 5-31. The voltage drop developed by a current flowing through the unknown ground resistance is measured by comparing it to a portion of the voltage drop developed by that same current flowing through a calibrated potentiometer. The current flowing through the calibrated potentiometer causes a voltage drop which is fed to the primary of the transformer, inducing a voltage in the secondary, causing a current flow in the measuring circuit. This current tends to cancel the existing current in the measuring circuit due to the voltage drop across the ground resistance between the electrodes connected to terminals X and 1. When the calibrated potentiometer and range switch are adjusted so that the two currents exactly cancel, the galvanometer will indicate balance by resting in the zero position. The reading on the calibrated dial of the potentiometer, multiplied by the range switch setting, then gives the value of the ground resistance of the point under test.

Representative test setups are shown in figures 5-32 and 5-33.

Grounding must be in accordance with the National Electrical Code, published by the National Board of Fire Underwriters and the National Electrical Safety Code, published by the U. S. Department of Commerce, National Bureau of Standards, except that grounds and grounding systems must have a resistance of solid earth ground not exceeding the following values:

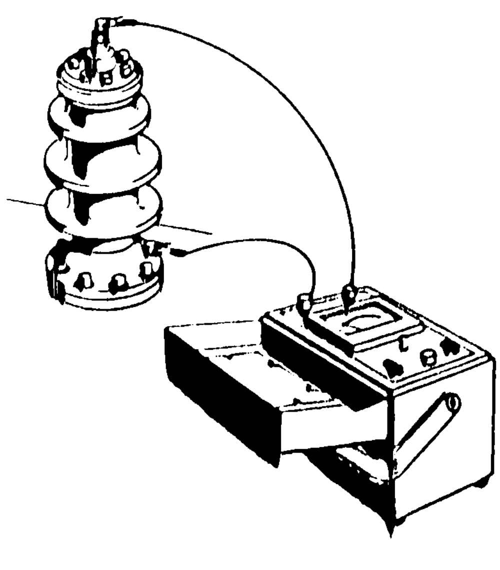
	Ohms
Generating stations	1
Main substations, distribution substations, and switching stations on primary distribution system	3
Metal enclosures of electrical and electrically operated equipment and cable sheaths of connecting cables	3
Systems to which portable electrical utilization equipment or appliances are connected	3
Secondary distribution systems (neutral), noncurrent carrying metal parts associated with distribution systems, and enclosures of electrical equipment not normally within reach of other than authorized and qualified electrical operating and maintenance personnel	10
Individual transformer and lightning arrester grounds on a distribution system	10
Equipment not covered above	10

Insulator Test

Insulators, the "forgotten men" of electrical systems, are subject to several ills that can make them a potential hazard unless they are tested periodically. Breakage is probably the first hazard with insulators. Casually accumulated dirt, grease, or liquids is another. Occasionally, faulty construction makes a brand new insulator a source of danger. To test insulators, connect test leads to each end; then test each end to ground (fig. 5-20).

Capacitor Test

You can use the Vibrotest megohmmeter to check both insulation resistance and approximate capacitance of capacitors. When you connect leads to capacitor terminals, observe polarity carefully. Time your test until the meter pointer stops moving upward, then record insulation resistance at highest reading. Dividing test time, in seconds, by 15 will give you the approximate capacitance, in microfarads, of the capacitor. If one pointer has a tendency to waver toward the high reading, then drop back down the scale. The capacitor may be leaking, and further testing is indicated. Be especially careful to RELEASE PUSHBUTTON before starting to disconnect test leads from capacitors. If you do not give the Vibrotest discharge resistor an opportunity to dissipate the stored



73.282X

Figure 5-20. Testing insulators.

shock.

Transformer Test

Deenergize equipment. Disconnect the leads from both primary and secondary windings. Tests can be made of either the primary or secondary winding individually by connection of the negative lead an associated ground (case, metal mounting, or manmade ground), and the lead from the winding under test to the positive lead. Following tests of each winding, it is a good idea to test insulation resistance between the windings themselves. Connect one test lead to the primary (either lead); and the second test lead to the secondary. All of these tests, under proper identifying labels, should be recorded on a record card.

If you have transformers with multiple-voltage windings, the procedures above should be followed to test all windings to ground, and each winding's resistance value to every other winding.

Tests should be made during clear, dry weather. The temperature and relative humidity of the air and general atmospheric conditions should be recorded at the time tests are being made, if known. Test records should be kept since they show when trouble is developing as a result of gradual or sudden deterioration of the insulation or because of local leakage. For example, a 40-megohm reading on the primary winding of a transformer that has been testing about 500 megohms indicates trouble that should be remedied. Low resistance values may require oil samples to be taken from the transformer to determine whether or not the low values may be due to deterioration of the oil.

PHASE SEQUENCE INDICATOR

The PHASE SEQUENCE INDICATOR is a device used to compare the phase rotation of an incoming alternator operated in parallel with an alternator already on the line; or to determine the phase rotation of equipment being put into use for the first time.

The makeup of a phase sequence indicator is as follows: A tiny three-phase induction motor is equipped with three leads, labeled A, B, and C, as shown in figure 5-21. The insulating hoods over the clips are of different colors; red for A, white for B, and blue for C.

The rotor in the instrument can be observed through the three PORTS as it turns, so that

73.52
Figure 5-21. —Phase-sequence indicator.

you can note the direction in which it rotates. The rotor can be started by means of a momentary contact switch; it stops again when you release the switch.

Phase sequence is the sequence or order in which the three voltages of a three-phase system appear. When an incoming alternator is cut in with a loadside alternator already in operation, connections must be made so that the phase sequence of the two will be the same.

Figure 5-22 illustrates the procedure for ensuring this with a phase sequence indicator. Connect indicator terminal A to X_1, B to Y_1, note the direction of rotation of the rotor.

Now move the A terminal to X, the B to Y, and the C to Z, and again press the switch. If the rotor turns in the same direction as before, the phase rotation is the same and the connection can be made X to X_1, Y to Y_1, and Z to Z_1. If the rotor turns in the opposite direction, transpose the connections of any two of the incoming alternator leads before making the connection.

Now move the A terminal to X, the B to Y, and the C to Z, and again press the switch. If the rotor turns in the same direction as before, the phase rotation is the same and the connection can be made X to X_1, Y to Y_1, and Z to Z_1. If the rotor turns in the opposite direction, transpose the connections of any two of the incoming alternator leads before making the connection.

It is not absolutely necessary that A be connected to the left-hand terminal, B to the center terminal, and C to the right-hand terminal. This is a practical method, however, used to avoid the danger of confusing the leads. The important thing is to ensure that the phase sequence indicator that was used on X_1 be brought down to X, the one used on Y_1 to Y, and the one used on Z_1 to Z. Reversing any two of the leads will reverse the direction of rotation of the rotor.

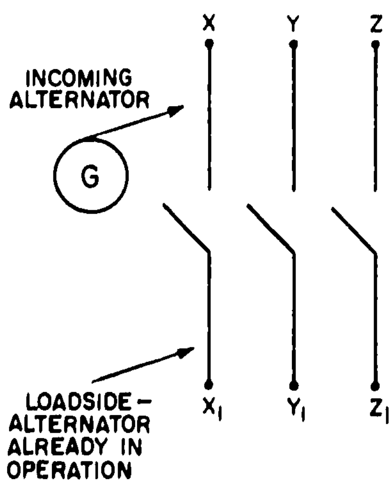


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Figure 5-22.—Diagram for checking phase sequence.

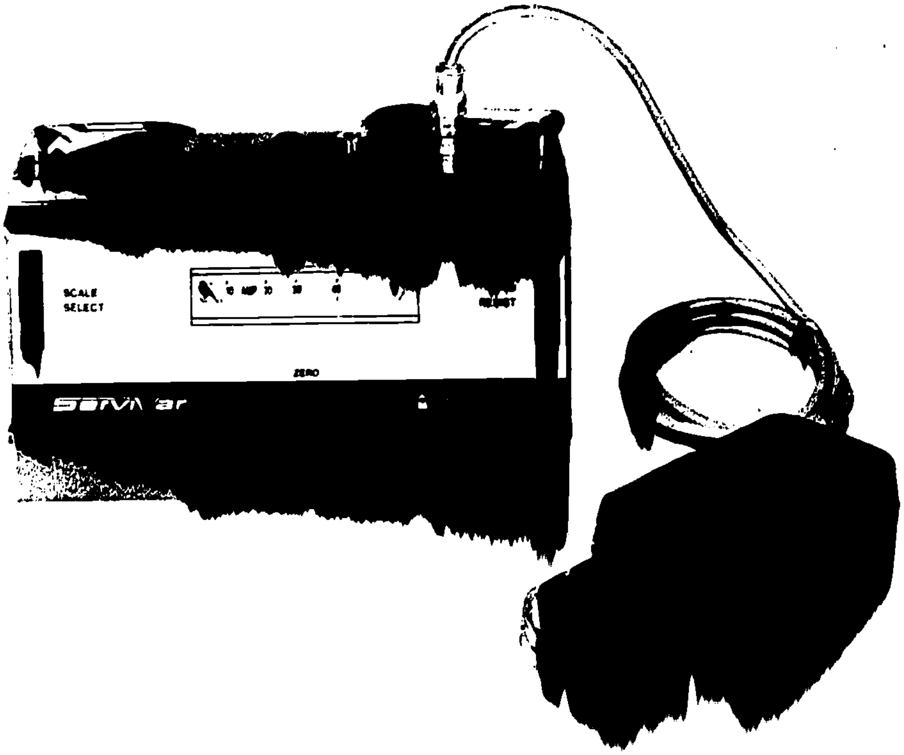
SPECIAL TEST EQUIPMENT

In addition to the basic test instruments described in the previous sections, it is necessary that you acquaint yourself with various special test instruments. A description of a number of special test instruments used by the CE is presented in the following sections.

SERVIVAR ELECTRICAL TESTER

The Servivar Electrical Tester is a multipurpose electrical instrument designed for resistance, and alternating current and voltage measurements. It is a portable, battery-operated unit consisting of the basic indicator instrument (fig. 5-23), an attachable Snap-Around probe for measuring a-c currents (fig. 5-24) and a Line Splitter (fig. 5-25).

Only one scale on the instrument is visible to the user at any given time. This eliminates or reduces confusion and erroneous readings so common to multiple scale instruments. The scales

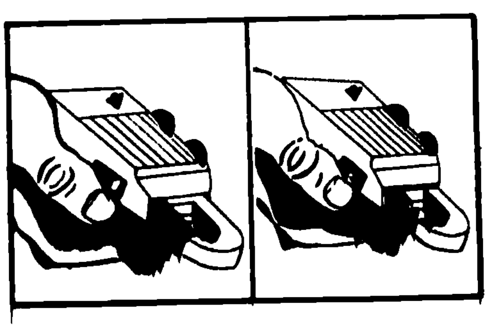


26,230X

Figure 5-23.—Servivar electrical tester.

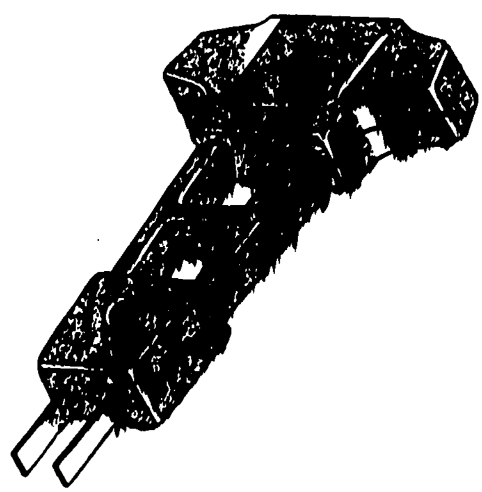
re color coded so that the user can quickly ecognize whether he is on the a-c current cale, a-c volt scale, or the ohm scale.

Special circuitry (not shown) prevents damage ɔ the meter when voltage is applied inadvert-ntly to the instrument when it is on the ohm cale. This is accomplished without the use



26,231X

Figure 5-24.—Snap-around probe.



26,232X

Figure 5-25.—Line splitter.

of fuses, circuit breakers, or other devic[illegible] that would have to be replaced or reset.

Principles of Operation

The a-c current to be measured is intercepted from the conductor in which it is flowing by transformer action in the magnetic path that constitutes the Snap-Around probe. A pick-off coil located inside the probe and around the magnetic path surrounding the reference conductor supplies voltage to a full-wave bridge through a resistance network. This voltage varies in magnitude in direct proportion to the current that is being measured.

Probe

The probe has been designed to enter into cramped electrical boxes and to snap around an individual conductor in a mass of conductors without the need to reposition the other conductors. It operates as a true Snap-Around device that accepts wires up to 0.5 inch outer diameter, rather than a cumbersome scissors type jaw that requires a maximum clearance.

The probes are interchangeable with all indicators so that additional probes may be left permanently installed in inaccessible locations.

The Snap-Around probe features easy thumb control for quick opening. Retraction is a simple operation. Merely slide the thumb knob back and hold at the desired clearance. (See fig. 5-24.) To close, release gently, encircling the wire whose current is to be determined.

Line Splitter

As you know, in measuring a-c current, it is mandatory that only one conductor be encircled. It may not be convenient or possible to split the conductors in a two conductor cable so that a current measurement can be made. The line splitter automatically performs this function.

WESTON MODEL 639 INDUSTRIAL ANALYZER TYPE 3

The Weston Model 639 Industrial Analyzer Type 3 can be used to measure the complete load conditions of any three-phase four-wire system when used with proper current and potential transformers (fig. 5-26). Switches permit testing of 60- or 400-hertz power circuits. [illegible]er factor [illegible] bined into one instrument and selection is made by another switch.

Adapters

Adapters are available for use on single- and three-phase, 3-wire measurements and may expedite testing procedure. These adapters include: Model 9815 Type 1 Adapter for three-phase 3-wire 200/100/50/5-ampere operation; Model 9815 Type 2 Adapter for single-phase 2-wire 100-ampere operation; and Model 9815 Type 3 Adapter for single-phase 2-wire 50-ampere operation.

Precautions

You should remember the following precautions when using the analyzers:

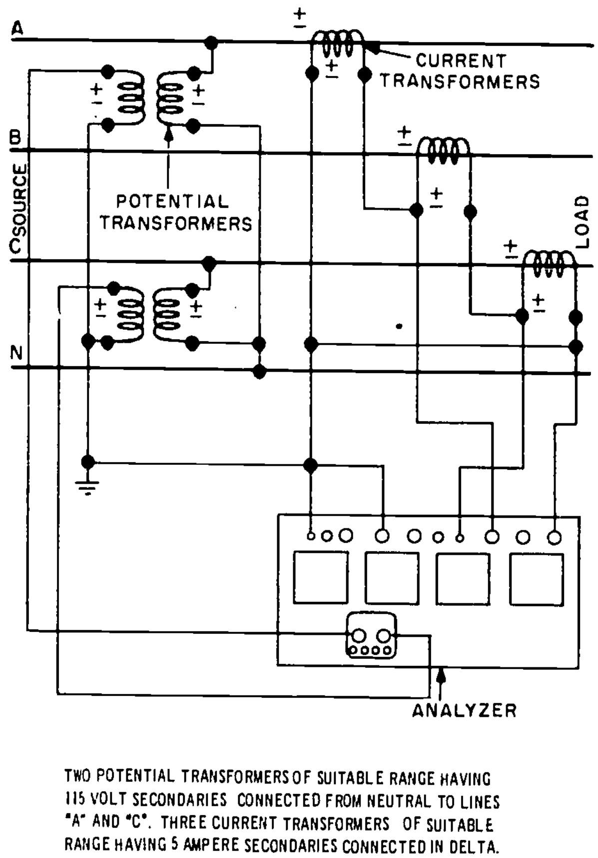
1. Always set switches to the proper settings and ranges before connecting the instrument.
2. Always connect the load leads to the same current on all three phases of the instrument and to a high enough range so that the current indicated will be below the full scale deflection of the ammeter.
3. NEVER USE THESE INSTRUMENTS FOR D-C MEASUREMENTS.

Connecting Analyzer to Circuits

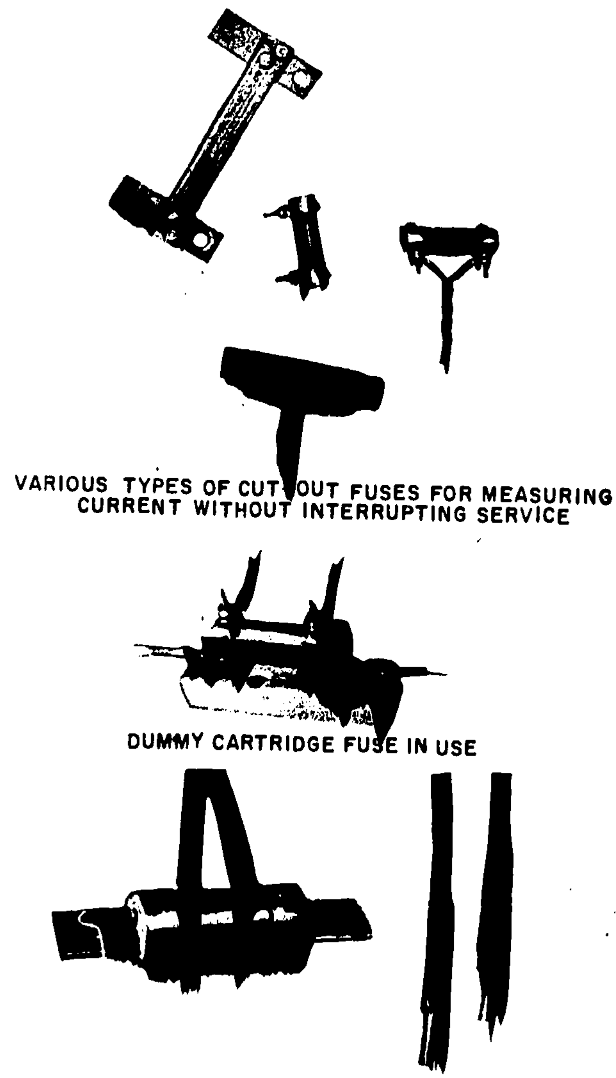
The three-phase, 4-wire hookup in figure 5-27 shows a schematic of external potential and current transformers. Improper connection could result in damage to personnel and equipment. Therefore, follow the manufacturer's instructions carefully when connecting analyzers to circuits.

Ensure that all cables used for connections to source or load are of sufficient size to carry the currents involved and are connected securely to the binding posts and the circuit terminals. Refer to Table 310-13 (National Electric Code) for information regarding the allowable ampacities of insulated copper conductors, for more data pertaining to cables.

BE SURE TO USE THE APPROPRIATE CORRECTION FACTOR (bottom of Table 310-13) wherever the ambient temperature exceeds 86° F. For example, if you plan to use THW conductor, and the ambient temperature at your station is 113° F, notice that the current carrying capacity of the size of wire you intend to use



26.40X
Figure 5-27.—Three-phase, 4-wire circuit connected to three current transformers.



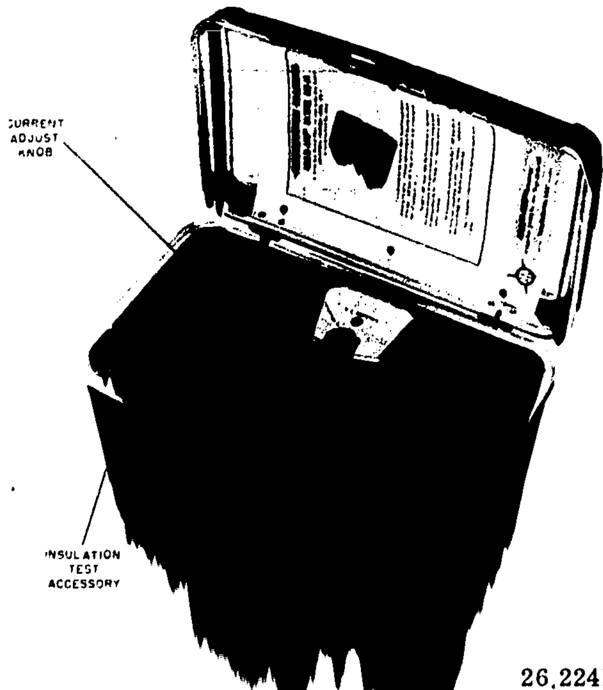
26.31X
Figure 5-28.—Various types of dummy fuses.

The instrument test relays from 0.1 to 100 amperes and circuit breakers up to 100 ampere capacity, measuring accurately the time-current characteristics of these devices with a synchronous electronically actuated timer.

The MultiAmp (MS-1A) instrument (fig. 5-29) is used primarily in Public Works installations. Testing is rapid. It takes but a few minutes to know your equipment is properly protected.

The instrument can be used to check the overload heaters of small motors. Refer to manufacturer's data sheets or Allowance Parts Lists for the tripping time characteristics for the particular overload heater. After setting the Current Adjust knob to that current which is supposed to trip the device and noting on the Timer the time it takes for the device to trip, a comparison is made with the manufacturer's specifications. Obviously, any results beyond the specified limits will indicate a defective relay which should be replaced or, if adjustable, reset to meet the specifications.

Use of this instrument will expedite determination of relay malfunctions or circuit faults. Assured of relay accuracy, after testing, you know the cause of difficulty (if the relay keeps tripping) lies within the circuitry other than the relay and must be sought there.



26,224X

'igure 5-29.—MultiAmp mod S-1A test set.

An accessory to the MS-1A tester, used or insulation measurements, fits into the ac-essory socket in the test lead compartment fig. 5-29). With it, insulation measurements rom 2 to 1000 megohms with ±5 percent ac-uracy can be made.

MODEL VIBROGROUND

Electrical systems and specific electrical equipment must be protected from damage or lestruction by voltages from other circuits, or lightning. Manmade grounds provide this safety feature. To provide maximum protection, hese grounds must be checked regularly.

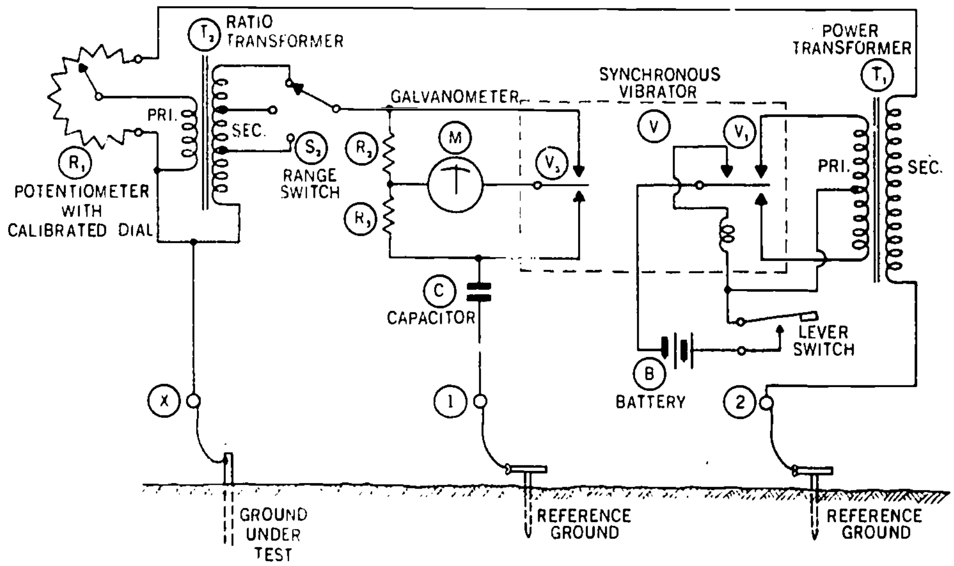
Figure 5-30 shows the Vibroground, an in-strument specifically designed to check grounds quickly and accurately.

The Vibroground works on a null-balance principle. The basic circuit is indicated in 'igure 5-31. The voltage drop developed by a current flowing through the unknown ground resistance is measured by comparing it to a portion of the voltage drop developed by that same current flowing through a calibrated po-tentiometer. The current flowing through the calibrated potentiometer causes a voltage drop former, inducing a voltage in the secondary, causing a current flow in the measuring cir-cuit. This current tends to cancel the existing current in the measuring circuit due to the voltage drop across the ground resistance be-tween the electrodes connected to terminals X and 1. When the calibrated potentiometer and range switch are adjusted so that the two cur-rents exactly cancel, the galvanometer will indi-cate balance by resting in the zero position. The reading on the calibrated dial of the po-tentiometer, multiplied by the range switch set-ting, then gives the value of the ground resist-ance of the point under test.

Representative test setups are shown in fig-ures 5-32 and 5-33.

Grounding must be in accordance with the National Electrical Code, published by the Na-tional Board of Fire Underwriters and the Na-tional Electrical Safety Code, published by the U. S. Department of Commerce, National Bureau of Standards, except that grounds and grounding systems must have a resistance of solid earth ground not exceeding the following values:

	Ohms
Generating stations	1
Main substations, distribution sub-stations, and switching stations on primary distribution system	3
Metal enclosures of electrical and electrically operated equipment and cable sheaths of connecting cables	3
Systems to which portable electrical utilization equipment or appliances are connected	3
Secondary distribution systems (neutral), noncurrent carrying metal parts associated with distribution systems, and en-closures of electrical equipment not normally within reach of other than authorized and qualified elec-trical operating and maintenance personnel	10
Individual transformer and lightning arrester grounds on a distribu-tion system	10
Equipment not covered above	10



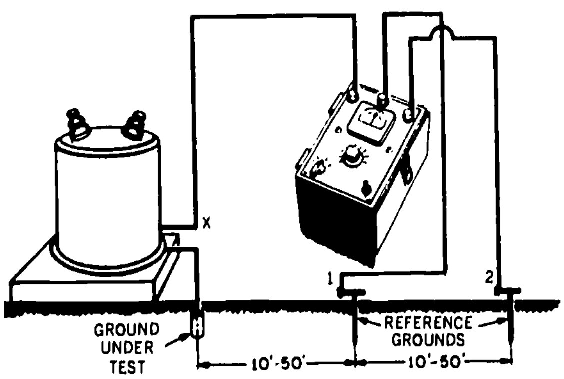
1.55AX

Figure 5-31.—Basic Vibroground circuit.

easurement of Unknown Resistances

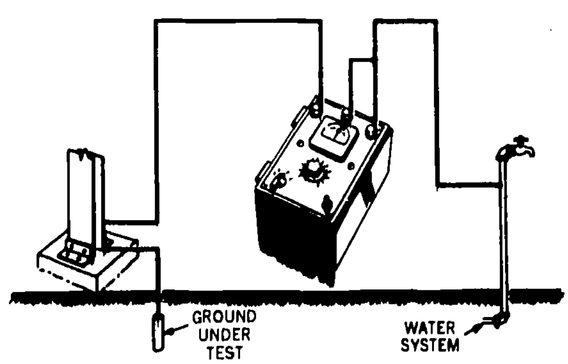
Once the instrument accuracy has been veri-ed, and the resistance of a loop or other esistance is to be determined, measurement an be easily made by referring to table 5-1 nd setting the MULTIPLY BY dial to that etting closest to the estimated value of the nknown resistance.

If the resistance of a loop is to be determined, disconnect all equipment from the near end of the loop and connect one wire of the loop to the binding post X_1 and the other wire to line binding post X_2 (fig. 5-35). Be sure that the wires connected to the test set are clean and firmly secured to the binding posts. Have all equipment disconnected from the far



26.227X

igure 5-32.—Vibroground test setup for checking the resistance to earth of a driven transformer ground.



26.228X

Figure 5-33.—Vibroground test setup when there is a well established low resistance reference ground.

ıble 5-1.—Multiply by Dial Setting When Measuring Resistance

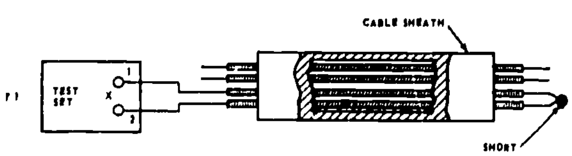
STIMATED RESISTANCE (ohms)	MULTIPLY BY dial setting
elow 10	$\frac{1}{1000}$
) to 100	$\frac{1}{100}$
)0 to 1,000	$\frac{1}{10}$
sed in Varley tests	$\frac{1}{9}$
sed in Varley tests	$\frac{1}{4}$
)00 to 10,000	$\frac{1}{1}$
0,000 to 100,000	$\frac{10}{1}$
0C,000 to 1,000,000	$\frac{100}{1}$

73.340

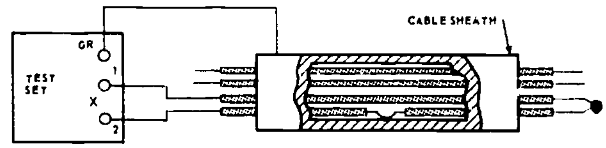
(1) The equation used to determine the restance from test point to fault (X_a) equals:

$$X_a = \frac{rB - AR}{A + B}$$

here r equals R_g + R_b (loop resistance).



26.44
igure 5-35.—Connection for measurement of loop resistance.



26.45
Figure 5-36.—Connections for ground location, regular Varley and Murray loop tests.

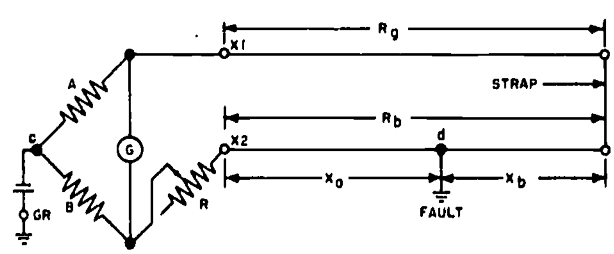
(2) The equation used to determine resistance from far end to fault (X_b) equals:

$$X_b = \frac{A(R + R_b) - BR_g}{A + B}$$

where A = numerator of position of MULTIPLY BY dial,
B = denominator of position of MULTIPLY BY dial,
r = loop resistance as calculated in previous paragraph, Measurement of Unknown Resistance,
R = decade dial reading after balancing,
R_g = resistance of good wire from test point to far end,
R_b = resistance of faulty wire from test point to far end.

Three Varley Test

This test has a definite advantage, especially for central desk testing, over other types of tests in that the resistance of the test cords and the conductors themselves neither need to be



26.46.1
Figure 5-37.—Regular Varley loop test circuit, simplified schematic diagram.

known nor allowed for in the calculations. Its chief drawback lies in the fact that a good pair (two conductors of any resistance) are needed in additio. to the faulty conductor and ground.

NOTE: Lead wires and conductors may be of unequal resistance, because this method balances out their resistances.

The test derives its name from the Varley Loop and from the fact that three such tests must be made. Howeve. each is simple as shown in the diagrams and any tester who can perform the simple Varley should achieve accurate results here. (See fig. 5-38 (a), (b), and (c).) The three tests made are known as "Varley 1", "Varley 2" and "Varley 3", using the connections as shown in figure 5-38 (a), (b), and (c).

Calling the rheostat readings at balance R_1, R_2, and R_3 respectively, the basic equations are:

$$\frac{A}{B} = \frac{R_g}{R_1 + R_b} = \frac{R_g + X_b}{R_2 + X_a} = \frac{R_g + R_b}{R_3}$$

From which may be obtained the working equations:

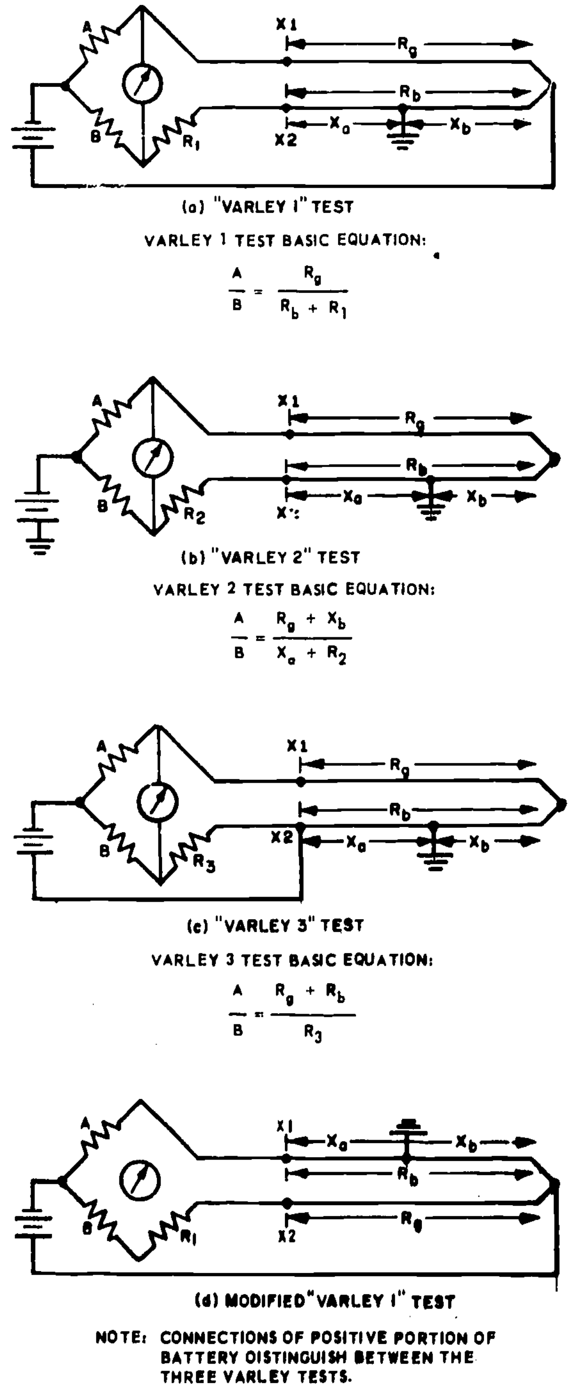
$X_a = \frac{A}{A + B} \times (R_3 - R_2)$ used to determine the resistance (X_a) between the test point and the fault.

$X_b = \frac{A}{A + B} \times (R_2 - R_1)$ used to determine the resistance (X_b) between the fault.

$R_b = X_a + X_b = \frac{A}{A + B} \times (R_3 - R_1)$ used to determine the resistance (R_b) of the full length of the faulty wire.

These symbols are identified in equation 2 under Regular Varley Loop Test.

In using the three Varley Test, MULTIPLY BY dial ranges 1/1, 1/4, or 1/9 are recommended. Once the range has been selected, it must be used on all three tests to produce accurate results.



26.46.2

Figure 5-38.—Simplified schematics and basic equations for "Three Varley tests."

To determine the resistance to the fault to tenths of an ohm, the ratio A/B must be approximately 1/10. The ratio 1/9 and 1/4 are convenient in some models, because their working equations reduce, respectively, to the forms:

$$X_b = \frac{R_2 - R_1}{10},\ X_a = \frac{R_3 - R_2}{10},\ \text{and}\ R_b = \frac{R_3 - R_1}{10}$$

$$X_b = \frac{R_2 - R_1}{5},\ X_a = \frac{R_3 - R_2}{5},\ \text{and}\ R_b = \frac{R_3 - R_1}{5}$$

When the total resistance of the loop is more than about 1000 or 1100 ohms, it is impossible to balance the bridge when using the 1/10 or 1/9 MULTIPLY BY dial setting. It may then be necessary to use A/B = 1. Then, if the good wire is of lower resistance than the faulty wire, the bridge cannot be balanced in the "Varley 1" test. The good and bad wires, with their leads, must interchanged as in figure 5-38 (d), while making the "Varley 1" test only. The working equations under these conditions are:

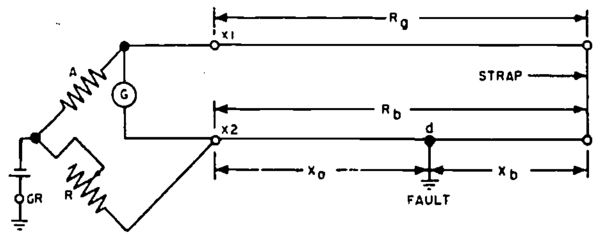
$$X_b = \frac{R_2 + R_1}{2},\ X_a = \frac{R_3 - R_2}{2}\ \text{and}\ R_b = \frac{R_3 - R_1}{2}$$

To avoid the need for interchanging the good and bad conductors in the "Varley 1" test, a small resistor may be connected between the test set and the good conductor. It is used during all three tests. Any reasonable value of resistance may be used which is large enough to make the resistance of the good conductor higher than that of the bad one. Its value need not be known since it is automatically eliminated by this method of test.

Murry Loop Test For
Locating a Ground

To use the Murray loop test for locating a ground, a good wire should be available (fig. 5-36) in addition to the grounded wire. A simplified schematic is shown in figure 5-39. Remove all equipment from both ends of the circuit and locate the fault using the manufacturer's instructions and either of the following methods:

(a) Direct computation, for solving d_a, the distance from the test point to the fault, when total mileage of loop is known.



26.46.3

Figure 5-39.—Regular Murray loop test for locating ground.

$$d_a = \frac{R \times L}{R + A},$$

where R equals the decade dial sum, L equals the total loop distance in miles and A equals the MULTIPLY BY dial reading (usually set at M 10, M 100, or M 1000 for Murray Loop readings).

(b) Resistance-distance method is used after the resistance X_a (from the test point to the fault) has been determined using the formula

$$X_a = \frac{R \times r}{R + A},$$

where R = total decade dial reading.

r = total loop resistance of the faulty circuit

A = numerator of the position of MULTIPLY BY dial.

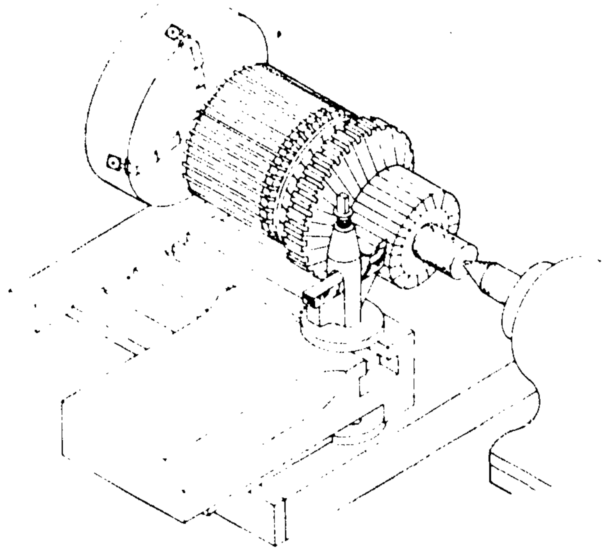
The result obtained from the above calculation is then substituted in

$$d_a = \frac{X_a}{1/2\ \text{resistance per loop mile}},$$

and should agree with the result calculated by the direct computation method.

CABLE REPAIRMAN'S TEST SET

The cable repairman's test set, I-51 (fig. 5-40) is used to pinpoint the location of cable faults after the approximate location of the fault has been obtained by the use of the Wheatstone Bridge or some other method. The test set can be used to locate shorts, grounds, crosses, split pairs, wet spots, and similar troubles in a cable. IT CANNOT BE USED TO LOCATE OPEN CIRCUITS.



77.74

Figure 7-7. — Truing commutator by turning.

Because there is a certain give, or elasticity, to the support, a heavy cut may result in the cylindrical shape of the commutator being impaired. Again, a heavy cut can cause the turning tool to twist the commutator bars, and to make deeper cuts at one end than at the other. Take light cuts, therefore, even though more cuts will thus be necessary.

The lathe must be capable of turning the part to be ground at exactly its rated speed; if the cutting is done at a lower speed, any slight unbalance will cause the commutator to turn eccentrically, when run at rated speed. The usual cutting speed is 100 ft per min (fpm), which is 1200 in. per min (ipm). The feed should be about 0.01 in., and the depth of the cut should not exceed 0.01 in.

The procedure for changing fpm to revolutions per min (rpm) is as follows. First determine the circumference in inches of the commutator by measuring with a cloth tape, or by measuring the diameter and multiplying by 3.1416. Divide the result into 1200 to obtain the number of rpm required for a cutting speed of 100 fpm.

For example, suppose you have an armature with a 6-inch commutator diameter. Multiply this measurement by 3.1416 and you get a circumference of 18.85 inches. Divide this into 1200 and you get 63.66 rpm which rounds off to 64 rpm.

Insulating mica protruding from the slots between the commutator bars can cause wear, streaking, and breaking of the brushes. Remove this high mica by undercutting it to a depth of between 3/64 and 1/16 inch below the level of the commutator bars with a power-driven flexible shaft undercutter, after first removing the brush rigging. If a power-driven tool is not available, use a slotting tool, or else make a cutter by removing the teeth from a hacksaw blade and forming one end. The straight end, taped, will serve as a handle. Figure 7-8 shows properly and improperly undercut commutators.

Do not use lubricant, and do not cut too deeply. After removing the high mica, smooth out all burrs and polish the commutator with a commercial burnishing stone or hardwood block shaped to the curvature of the armature. The block is pressed hard against the surface of the commutator while the machine is running.

Poor balance in an armature can cause commutator failure. Detach the armature from the machine, and rest the shaft ends on V-blocks. For a ball-bearing-supported armature, let the bearings remain on the shaft, and check the commutator with the shaft on V-blocks. The surface on which the V-blocks rest must be perfectly level in every case. To check for concentricity, use a dial gage mounted on a brush holder with the contact tip of the gage contacting the top of the brush and rotate the armature.

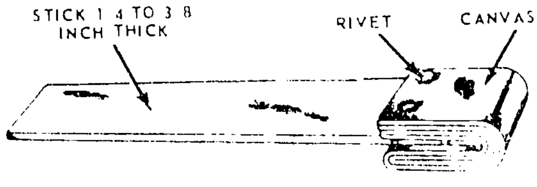
Commutators with peripheral speeds of approximately 5500 fpm should be concentric to within 0.001 inch. For commutators with peripheral speeds of about 9000 fpm, the allowable tolerance is only 0.0005 inch.

A

B

73.229

Figure 7-8. — (A) Commutator properly undercut; (B) Commutator improperly undercut.

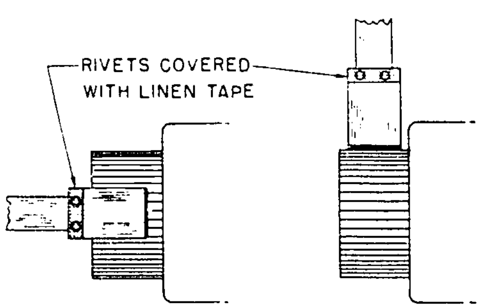


1.54.1
Figure 7-9. — Canvas wiper.

A check should be made on the air gaps at commutator poles, and at main poles, to determine if there is any wear or misalignment. You take the air gap measurement by setting a reference point on the armature (or rotor), and revolving it to measure four points on the stator (or the field frame) with reference to it. An equally satisfactory method is to choose your reference point on the stator or field frame, and revolve the rotor or armature to measure four points on the latter with reference to the stator point.

Correct tension on the commutator is usually determined at the time of manufacture. Tightening the commutator will not align the bars in their original position, and if the commutator becomes too tight, some of the bars may buckle. Making ringbolts and locknuts too tight may result in pressing the V-ring through the mica insulation, thus short circuiting the bars.

After being used approximately two weeks, the commutator of a machine should develop a uniform, glazed, dark brown color on the places where the brushes ride. If a nonuniform or bluish colored surface appears, improper commutation conditions are indicated. Periodic inspections and proper cleaning practices will keep commutator and collector-ring troubles at a minimum.



1.54.2
Figure 7-10. — Using the canvas wiper on a commutator.

Cleaning

One of the most effective ways of cleaning the commutator or collector rings is to apply a canvas wiper while the machine is running. The wiper can be made by wrapping several layers of closely woven canvas over the end of a strong stick between one-fourth and three-eighths inch thick (fig. 7-9). The canvas may be secured with rivets if they, in turn, are covered with linen tape to prevent the possibility of their contacting the commutator. When the outer layer of canvas becomes worn or dirty, it is removed to expose a clean layer. The wiper is most effective when used frequently. On large generators, it may be desirable to use the wiper once each watch. When using the wiper, exercise care to keep from fouling moving parts of the machine. The manner of applying the wiper to a commutator is illustrated in figure 7-10.

When machines are secured, a toothbrush can be used to clean out the commutator slots, and clean canvas or lint-free cloth may be used for wiping the commutator and adjacent parts. In addition to being cleaned by wiping, the commutator should be periodically cleaned with a vacuum cleaner or blown out with clean, dry air.

A fine grade of sandpaper, No. 00, may be used to clean a commutator that is only slightly rough, but not out of true. Sandpapering is recommended for reducing high mica, and for finishing a commutator that has been ground or turned. The sandpaper, attached to a wooden block shaped to fit the curvature of the commutator, is moved slowly back and forth across the surface of the commutator while the machine is running at moderate speed. Rapid movement or the use of coarse sandpaper will cause scratches. Emery cloth, emery paper, or emery stone should never be used on a commutator or collector ring.

COLLECTOR RINGS

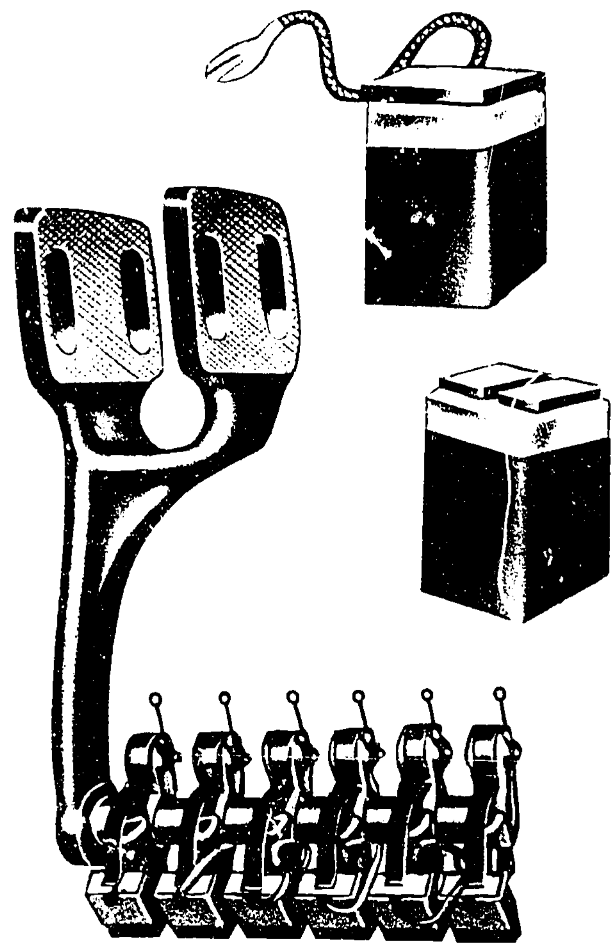
Collector rings (slip rings) require the same careful attention as the commutator. Out-of-round conditions of the rings may be corrected in the same manner as for commutators, except for the fact that crocus cloth is used to apply a mirror-like finish following any turning, grinding, or sanding operations.

Pitting can develop because of the electrolytic action on the surface of collector rings caused by current flow. It may occur in only one ring, but will be general over the whole ring area. This condition can be corrected by reversing the polarity of the rings every few days. Reversing the polarity of the d-c field of a 3-phase generator will not affect the phase rotation of the generator.

Field current must not be left on while a machine is secured because it will cause spot pitting and burning of the rings beneath the brushes.

BRUSHES

The brushes used in electric motors and generators are one or more plates of carbon, bearing against a commutator, or collector ring (slip ring) to provide a passage for electrical current for an external circuit. The brushes are held in position by brush holders (fig. 7-11) mounted on studs or brackets attached to the brush-mounting ring, or yoke. The brush holder studs or brackets, and brush-mounting ring comprise the brush rigging. A d-c generator brush holder and brush-rigging assembly are shown in figure 7-12. The brush rigging is insulated from, but attached to, the frame of the machine. Flexible leads (pigtails) are used to connect the brushes to the terminals of the external circuit. An adjustable spring is generally provided to maintain proper pressure of the brush on the commutator in order to effect good commutation.



73.165
Figure 7-11. — Brush holder and brushes.

Any defect in the brush riggings or maladjustment of the spring tension can impair the proper contact between the commutator and the brushes.

Maximum commutation is achieved when the correct grade brushes are set in the holders with allowable clearance and the appropriate spring tension applied to maintain the correct pressure for the particular type brushes.

Correct Brush Type

The correct grade of brush and correct brush adjustment are necessary to avoid commutation trouble. Brushes are manufactured in different grades to meet the requirements of the varied types of service. The properties of resistance, ampere-carrying capacity, coefficient of friction, and hardness of the brush are determined by the maximum allowable speed and load of the machine in which it is used.

Use the grade of brush indicated in the technical manual. Normally, similarly sized and graded brushes of any manufacturer on the Qualified Products List may be substituted. In certain specialized equipment, however, only one grade of each of two different brush manufacturers is permitted for any machine.

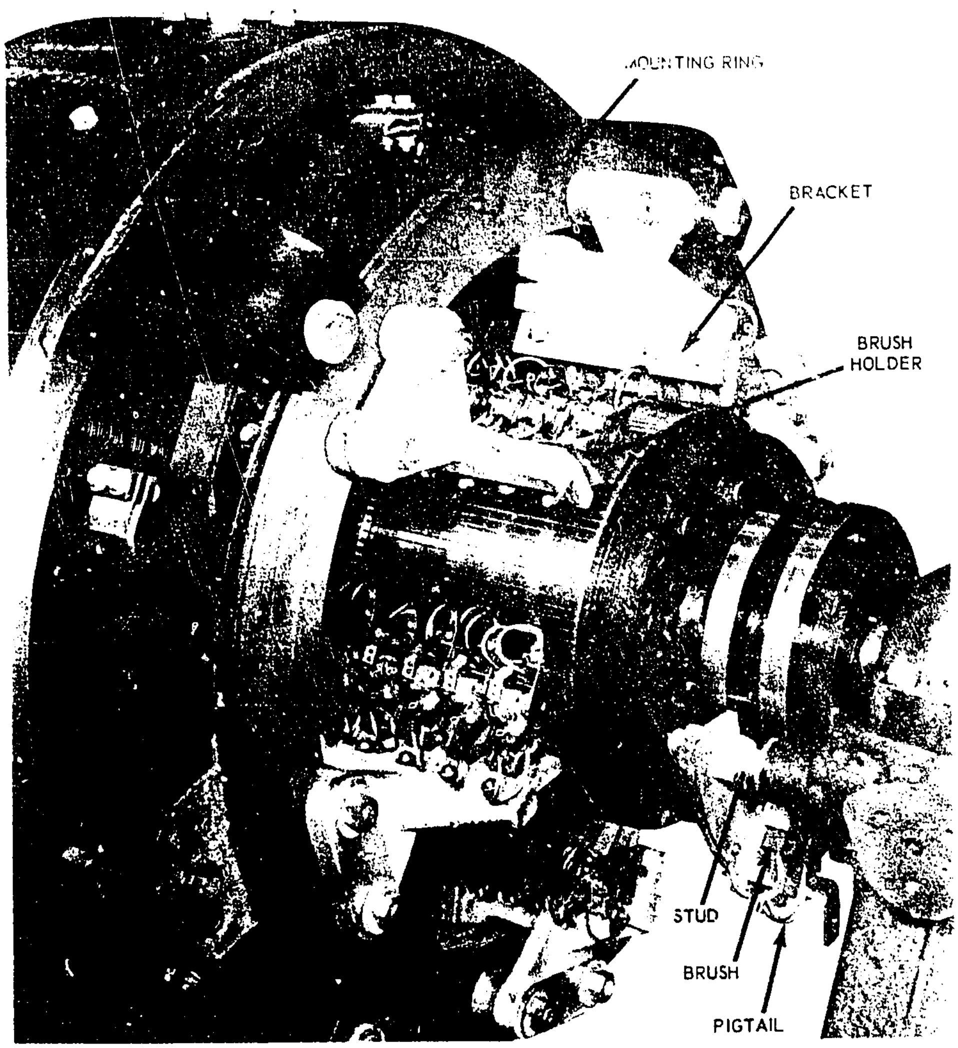
Care

Brushes should move freely in their holders but should not be loose enough to vibrate in the holder.

Brushes should be replaced when they are worn or chipped to such an extent that they will not move properly in their holders; or are worn to within 1/8 inch of the metallic part, or more than 50 percent of the original length of the brush.

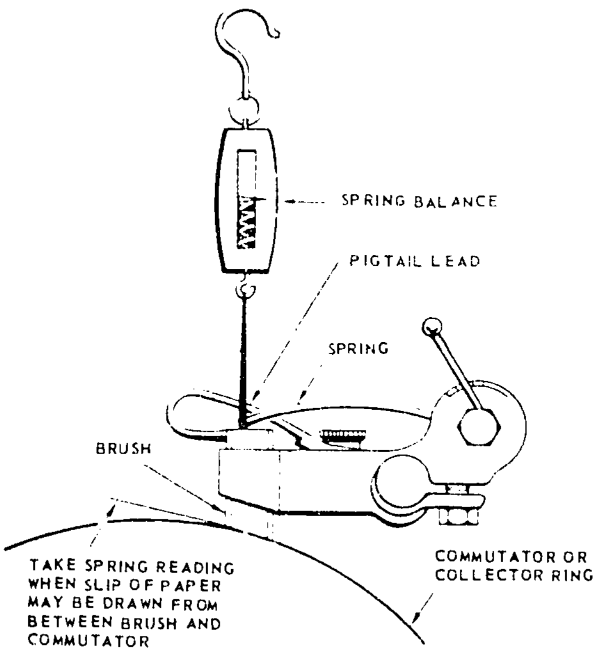
Replacement must be preceded by cleaning all dirt and other foreign material from the brush holder.

Where brush springs are of the positive gradient (torsion, tension, or compression) type and are adjustable, they should be adjusted as the brushes wear, in order to keep the brush pressure approximately constant. Springs of the coiled band, constant pressure type and certain springs of the positive gradient type are not adjustable except by changing springs. Brush



77.70

Figure 7-12. — Brush holder and brush-rigging assembly.



77.72

Figure 7-13. — Measuring brush tension.

pressure should be in accordance with the manufacturer's technical manual. Pressures as low as 1-1/2 pounds per square inch of contact area may be specified for large machines and as high as 8 pounds per square inch of contact area may be specified for small machines. Where technical manuals are not available, a pressure of 2 to 2-1/2 pounds per square inch of contact area is recommended for whole number horsepower and whole number kilowatt machines, and about twice that pressure for fractional horsepower and fractional kilowatt machines.

To measure the pressure of brushes operating in box type brush holders, insert one end of a strip of paper between the brush and commutator; use a small brush tension gage (such as the 0- to 5-pound indicating scale carried in General Stores under Stock No. GS6670-583-0063) to exert a pull on the brush in the direction of the brush holder axis as shown in figure 7-13. Note the reading of the gage when the pull is just sufficient to release the strip of paper so that it can be pulled out from between the brush and commutator without offering resistance. This reading divided by the contact area may be considered to be the unit operating pressure. Taking correction factors into consideration, the actual pressure will be a few percent lower in the case of brushes operating in the leading position and a few percent higher in the case of brushes operating in the trailing position.

All brush holders should be the same distance from the commutator, not more than one-eighth inch, nor less than one-sixteenth inch.

The toes of all brushes on each brush stud should line up with each other and with the edge of one commutator segment.

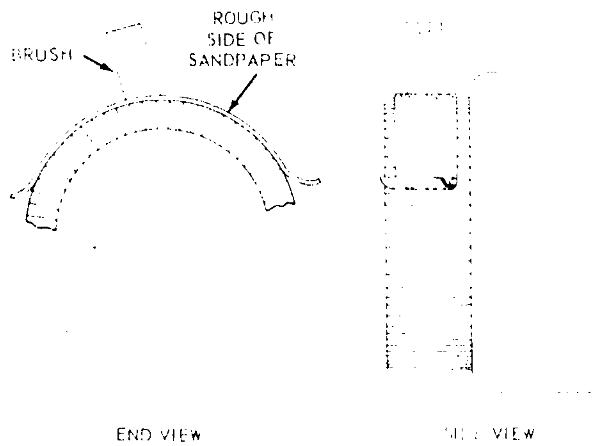
The brushes should be evenly spaced around the commutator. To check brush spacing, wrap a strip of paper around the commutator and mark the paper where the paper laps. Remove the paper from the commutator, cut at the lap, and fold or mark the paper into as many equal parts as there are brush studs. Replace the paper on the commutator and adjust the brush holders so that the toes of the brushes are at the creases or marks.

Seating

Accurate seating of the brushes must be assured where their surfaces contact the commutator. Sandpaper and a brush seater are the best tools to accomplish a true seat.

All power must be disconnected from the machine, and every precaution must be taken to ensure that the machine will not be inadvertently started before and whenever using sandpaper to seat the brushes. The brushes to be fitted are lifted, and a strip of fine sandpaper (No. 1) approximately the width of the commutator, is inserted (sand side up) between the brushes and the commutator. With the sandpaper held tightly against the commutator surface to conform with the curvature and the brushes held down by normal spring pressure, the sandpaper is pulled in the direction of normal rotation of the machine (fig. 7-14). When returning the sandpaper for another pull, the brushes must be lifted. This operation is repeated until the seat of the brush is accurate. Always finish with a fine grade of sandpaper, No. 0. A vacuum is required for removing dust while sanding. After sanding, the commutator and windings must be thoroughly cleaned to remove all carbon dust.

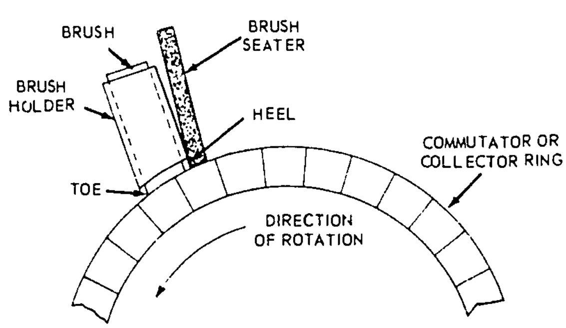
The brush seater is compounded of a mildly abrasive material loosely bonded, and is formed in the shape of a stick about 5 inches in length.



1.52
Figure 7-14.— Method of sanding brushes.

The brush seater is applied to the commutator while the machine is running, and every precaution should be taken to prevent injury to the person applying it. The brush seater is touched lightly, for a second or two, exactly at the heel of each brush (fig. 7-15). If placed even one-fourth inch away from the heel, only a small part of the abrasive will pass under the brush. Pressure may be applied to the brush by setting the brush spring tension at maximum or by pressing a stick of insulating material against the brush. The dust is removed during the operation, and the machine is thoroughly cleaned afterwards in the same manner as for sanding brushes.

Brushes should be staggered as shown in figure 7-16 to prevent grooving of the commutator.



1.53
Figure 7-15.— Using the brush seater.

For machines having a number of poles equal to two times an odd number, it will obviously not be possible to stagger all the brushes in accordance with the correct method shown. Stagger all but the odd pair of positive and negative brushes in accordance with the correct method, and the odd pair as shown in view B of figure 7-16.

Setting on Neutral

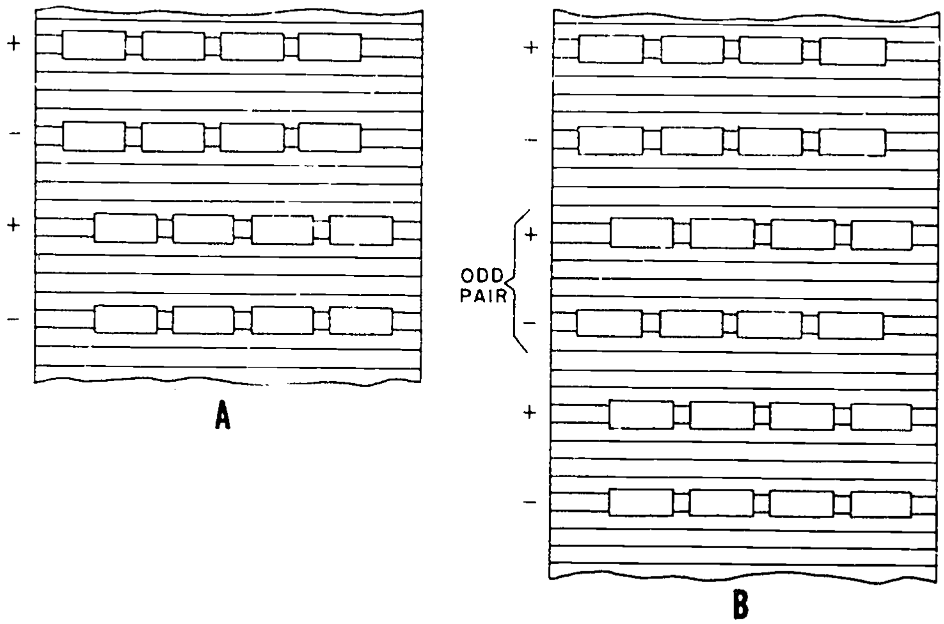
When a machine is running without load and with only the main-pole field windings excited, the point on the commutator at which minimum voltage is induced between adjacent commutator bars is the no-load neutral point. This is the best operating position of the brushes on most commutating-pole machines. Usually, the brush studs are doweled in the proper position, and the correct setting is indicated on a stationary part of the machine by a chisel mark or an arrow. In some cases, commutation may be improved by shifting the brushes slightly from the marked position.

The correct neutral position can be found by the use of:

1. The mechanical method.
2. The reversed rotation method.
3. The inductive kick method.

The mechanical method is an approximate method. Turn the armature until the two coil sides of the SAME armature coil are equidistant from the centerline of one MAIN field pole. The commutator bars to which the coil is connected give the position of the mechanical neutral.

Use of the reversed rotation method is possible only where it is practicable to run a machine in either direction of rotation, with rated load applied. This method differs for motors and generators. For motors, the speed of the motor is, at first, accurately measured when the field current becomes constant under full load at line voltage with the motor running in the normal direction. Then, the rotation of the motor is reversed, full load is applied, and the speed is again measured. When the brushes are shifted so that the speed of the motor is the same in both directions, the brushes will be in the neutral position. Generators are run at the same field strength and same speed in both directions,



77.71
Figure 7-16.—Correct method of staggering brushes.

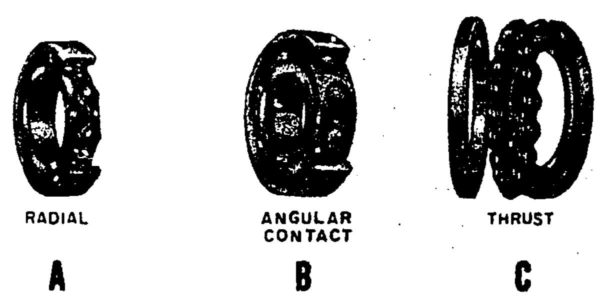
and the brushes are shifted until the full-load terminal voltage is the same for both directions of rotation. To ensure accuracy, a reliable tachometer must be used to measure the speed of the machines for this method.

The kick method should be used only when the other methods are inadequate and the conditions are such as to warrant the risks involved, and then only when sufficient resistance is connected in series with the field coils to reduce the field current to approximately 10 percent of normal value.

BALL BEARINGS

Rolling, antifriction bearings are of two types: ball and roller bearings. Basically, all rolling bearings consist of two hardened steel rings, hardened steel rollers or balls, and separators. The annular, ring-shaped, ball bearing is the type of rolling bearing used most extensively in the construction of electric motors and generators used in the Navy. This bearing is further divided into three types dependent upon the load it is designed to bear—(1) radial, (2) angular contact, and (3) thrust. Examples of these three bearings are shown in figure 7-17.

The rotating element of an electric motor or generator may subject a ball bearing to any one or a combination of three loads—radial, thrust, and angular. Radial loads are the result of forces applied to the bearing perpendicular to the shaft; thrust loads are the result of forces applied to the bearing parallel to the shaft; and angular loads are the result of a combination of radial and thrust loads. Because the load carried by the bearings in electric motors and generators is almost entirely due to the weight of the rotating element, it is apparent that the method



77.66
Figure 7-17.—Representative types of ball bearings.

of mounting the unit is a major factor in determining the type of bearing employed in its construction. In a vertically mounted unit, the thrust bearing would be used; while the radial bearing is common to most horizontal units.

The preventive maintenance of ball bearings requires periodic checks of bearing wear, and adequate lubrication.

Wear

Measuring air gaps to determine bearing wear is not necessary on machines equipped with ball bearings because the construction of the machine is such as to ensure bearing alignment. Ball bearing wear of sufficient magnitude as to be readily detected by air-gap measurements would be more than enough to cause unsatisfactory operation of the machine.

The easiest way of determining the extent of wear in these bearings is to periodically feel the bearing housing while the machine is running to detect any signs of overheating or excessive vibration, and to listen to the bearing for the presence of unusual noise. The indications thus obtained are comparative, and caution must be exercised in their analysis.

When testing for overheating, the normal running temperature of the bearing must be known before the test can be reliable. Rapid heating of a bearing is indicative of danger. While a bearing temperature uncomfortable to the hand may be a sign of dangerous overheating, it is not always so. The bearing may be all right if it has taken an hour or more to reach that temperature; whereas, serious trouble can be expected if that same temperature is reached within the first 10 or 15 minutes of operation.

The test for excessive vibration relies to a great extent on the experience of the person conducting the test. He should be thoroughly familiar with the normal vibration of the machine in order to be able to correctly detect, identify, and interpret any unusual vibrations. Vibration, like heat and sound, is easily telegraphed, and thorough search is generally required to locate its source and to determine its cause.

Ball bearings are inherently more noisy in normal operation than sleeve bearings, discussed later, and this fact must be borne in mind by personnel testing for the presence of abnormal noise in the bearing. A good method for sound testing is to place one end of a screwdriver or steel rod against the bearing housing and the other end against the ear. If a loud, irregular grinding, clicking, or scraping noise is heard, trouble is indicated. As before, the degree of reliance on the results of this test depends on the experience of the person conducting the test.

Checking a motor or generator shaft can give a good indication of the amount of wear, as shown in figure 7-18. View A illustrates that if the motor shaft has vertical movement, worn bearings are indicated. View B illustrates motor or generator end-play movement and is corrected with bearing shims.

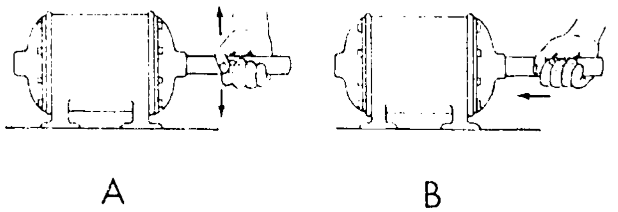
Bearing Installation

Representative techniques for bearing removal are shown in figures 7-3 and 7-4. Four acceptable methods for installing bearings exist. These are called the arbor press, infrared, oven, and hot-oil methods. The technique you use will depend upon the equipment available.

ARBOR PRESS METHOD.—If available and adaptable, and proper precautions are taken, an arbor press can be used. Place a pair of flat steel blocks under the inner ring or both rings of the bearing. Never place blocks under the outer ring only. Then line up the shaft vertically above the bearing, and place a soft pad between shaft and press ram. After making sure the shaft is started straight in the bearing, press the shaft into the bearing until the bearing is flush against the shaft or housing shoulder.

INFRARED METHOD.—A bearing can be heated using an infrared oven to expand the inner ring for assembly. The bearing should not be heated above 200° F. This method ensures uniform heating all around the bearing.

OVEN METHOD.—Alternatively, bearings can be heated to expand the inner ring for assembly in a temperature-controlled furnace at a temperature not to exceed 200° F. The bearing should not be left in the furnace beyond the time necessary to expand the inner race the desired amount, since heating for an excessive period of time would give rise to the possibility of deterioration of the grease with which the bearing is prelubricated.



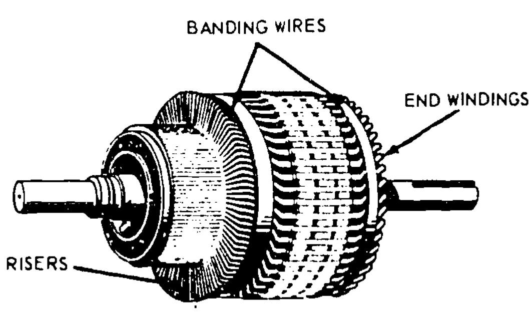
73.390
Figure 7-18.—Checking motor or generator shafts. (A) Vertical movement; (B) End-play movement.

HOT-OIL METHOD.—A fourth method used in installing bearings is the hot-oil method, which consists of heating the bearing in oil at 200° F until expanded and then slipping it on the shaft. This method is not desirable and should not be used unless absolutely necessary.

Note: When pressing a bearing onto a shaft, pressure must be applied to the inner ring, but when pressing a bearing into a housing, pressure must be applied to the outer ring.

Before the final assembly has been completed, the entire unit should be thoroughly checked for alignment.

The bearing should be packed with the proper lubricant and the cleaned bearing housing should be half filled with the same lubricant. The housing must be properly assembled and care must be exercised to prevent omission of bearing parts, lubricant seals, grease pipes, plugs, and fittings. These parts must be securely assembled to complete the housing closure and protect against



5.143
Figure 7-19.—A d-c armature.

the entrance of foreign materials. Both should be tightened evenly. Any "V" grooves in the housing lip should be filled with grease which will act as an additional seal to protect against entrance of dirt.

ARMATURES

Preventive maintenance of an armature consists of periodic inspections and tests to determine its condition, and proper cleaning practices to preserve the insulation.

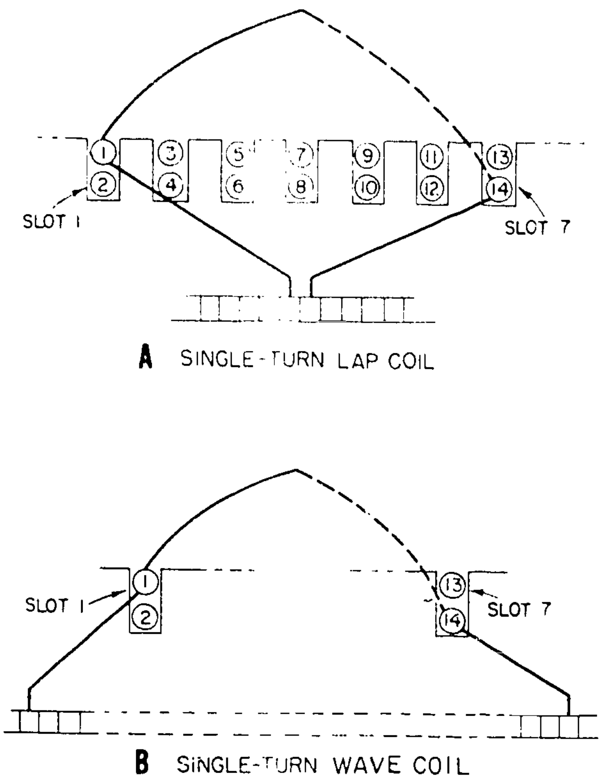
Frequent checks must be made of the condition of the banding wire that holds down the windings of the d-c armature to see that the wires are tight, undamaged, and have not shifted (fig. 7-19). At the same time, the clips securing the wires should be checked to see if solder has loosened. When repairs are required, banding-wire size, material, and the method of original assembly should be duplicated as far as possible. Only pure tin must be used for soldering banding wire.

Periodically, all end windings should be inspected and cleaned (fig. 7-19). Allow sufficient clearance between the end windings and end brackets or any air deflecting shields to prevent chafing or other damage. In cases where shop overhaul is not feasible, air-drying varnish may be applied to the windings by brush after they have been cleaned and dried.

Risers must be inspected periodically to determine the condition of the solder that secures the windings to the segments (fig. 7-19). All dirt and lint should be removed by thorough cleaning to ensure that cooling passages will not be clogged. It may be necessary in the case of generators to do this each time the machine is secured. Cleaning is easier when performed while the machine is warm.

Winding Identification

It is important for you to be able to identify armature windings because the type must be determined in order to understand the trouble indications and to make the necessary repairs. Your complete understanding of LAP, WAVE, PROGRESSIVE, and RETROGRESSIVE windings is vital. Furthermore, your understanding and application of terms such as PITCH, COIL

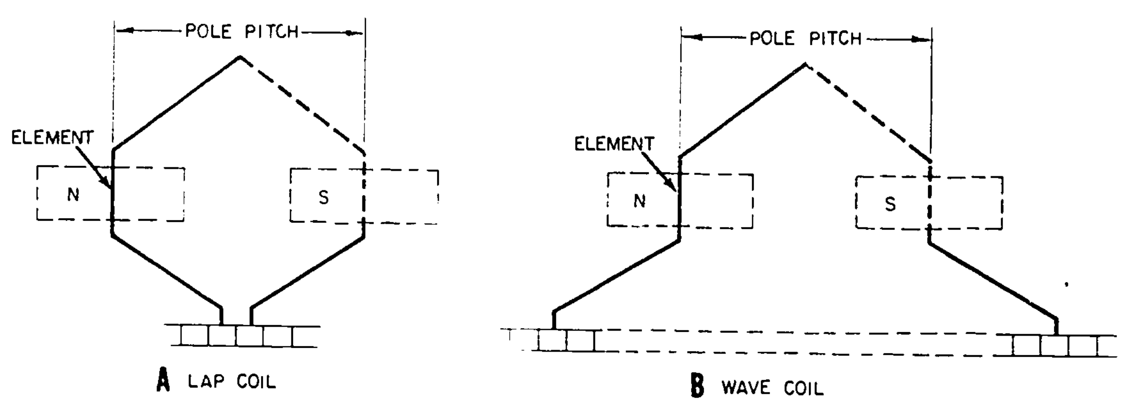


111.1
Figure 7-20.—Classification of armature windings.

PITCH, and SIMPLEX, DUPLEX and TRIPLEX connections will enable you to perform your jobs quickly and efficiently.

LAP AND WAVE WINDINGS.—Armature windings, irrespective of how the elements are placed on the armature core, are generally classified as LAP or WAVE windings. The classification designates the method of connecting the ends of the elements, or coils, to the commutator (fig. 7-20). If the ends of the coil are connected to adjacent commutator segments, or to segments that are close together, the coil is designated as a lap-connected coil, and the winding is a lap winding (view A of the figure). On the other hand, if the ends of a coil are connected to commutator segments approximately two pole pitches apart, the coil is designated as a wave-connected coil, and the winding is a wave winding. (See fig. 7-20, view B and fig. 7-21.)

PITCH.—Both lap and wave windings are placed on the armature core so that the two sides of an element occupy slots that are influenced by adjacent poles of opposite polarity, and the emf's generated in the two sides add together. In other words, if the left side of a coil momentarily occupies a position under the center of a north pole, the right side of the same coil will occupy a position under approximately the center of an adjacent south pole. The distance between the centers of two adjacent poles is the pole pitch. The span of one coil should be equal or nearly equal to one pole



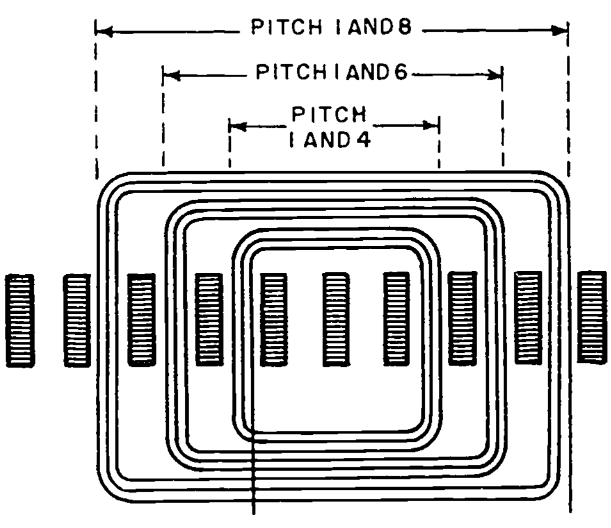
111.2

Figure 7-21.—Full-pitch coils.

pitch. If a coil spans exactly one pole pitch, the winding is FULL PITCH (fig. 7-21), and if a coil spans less than one pole pitch, the winding is FRACTIONAL PITCH. COIL PITCH is recorded and identified by the number of slots spanned by the coil in the armature (fig. 7-22).

NUMBERING. — Usually d-c armature windings are two-layer windings in which each slot contains two coil sides of a single-coil type of winding (fig. 7-20). Thus one side of the winding element is placed in the top of a slot, and the other side is placed in the bottom of another slot. It is immaterial which side of the element is placed in the top or bottom of the slot. In practice (observing the armature from the commutator end) the right side of the coil is usually placed in the bottom of one slot and the left side is placed in the top of another slot. The coil sides are arbitrarily numbered so that all TOP coil sides have odd numbers and all BOTTOM coil sides have even numbers (fig. 7-20). This system helps to place the coils properly on the armature.

PROGRESSIVE AND RETROGRESSIVE WINDINGS. — Lap and wave windings can be progressive or retrogressive, as illustrated in figure



73.132
Figure 7-22. — Progressive and retrogressive windings.

7-23. A PROGRESSIVE WINDING (view A) progresses in a clockwise direction around the armature when traced through the winding from the commutator end. In other words, the winding progresses clockwise from segment (bar) through the coil to segment.

Progressive wave winding and retrogressive lap windings are very seldom encountered because of the inherent undesirable features, such as the end connections of coil groups crossing over each other, added weight, and longer leads. Therefore, with few exceptions lap windings are progressive and wave windings are retrogressive.

A RETROGRESSIVE WINDING (view B of fig. 7-23) progresses in a counterclockwise direction around the commutator end.

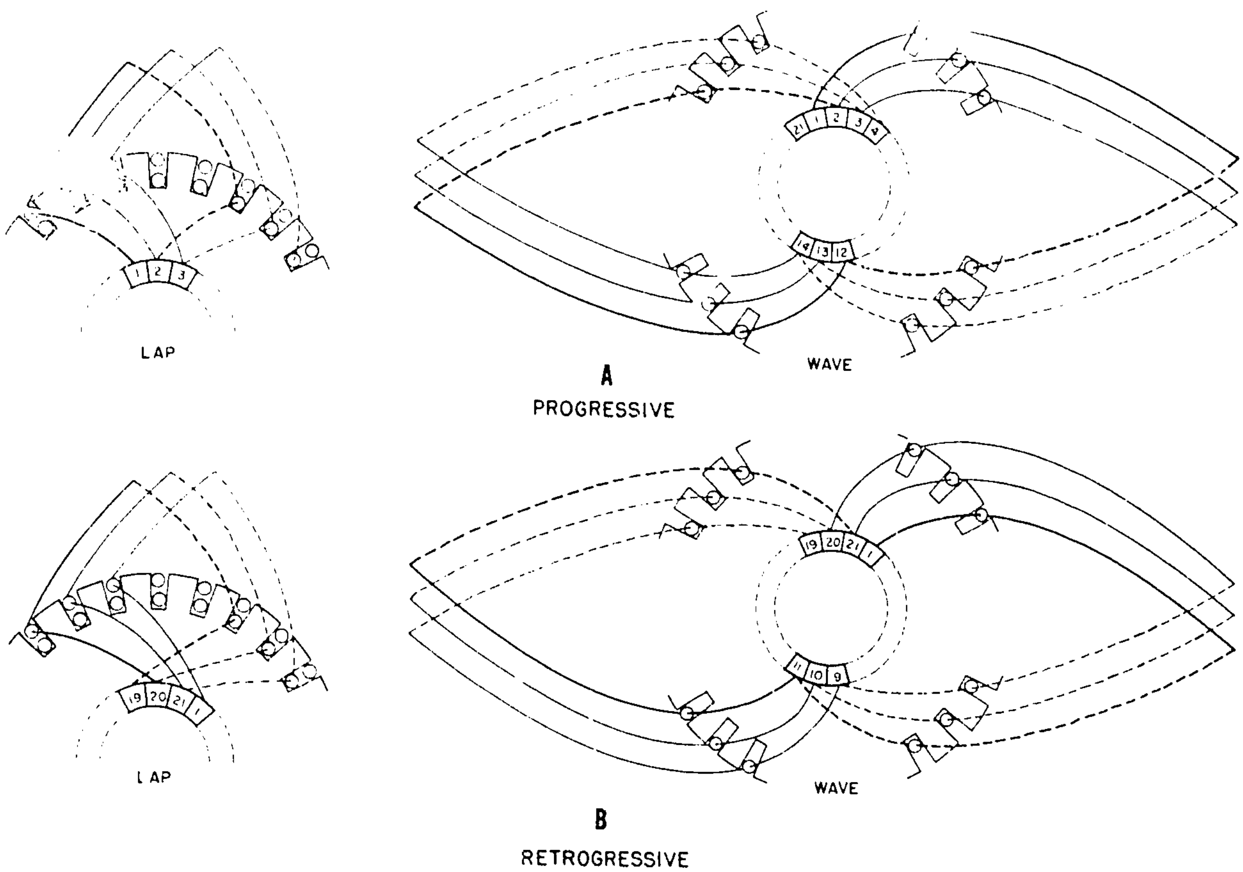
MULTIPLEX WINDINGS. — Windings may also be classified and connected in SIMPLEX, DUPLEX, or TRIPLEX. A simplex lap winding is one in which the beginning and ending leads of a lap wound coil are connected to adjacent commutator bars. Duplex lap winding leads are connected two bars apart, and triplex lap winding leads are connected three bars apart.

Progressive and retrogressive simplex lap windings are shown in figure 7-24. As you can see, the progressive lap winding is one in which the current flowing in a coil terminates in the commutator bar clockwise adjacent to the starting bar as you view the armature from the commutator end. A retrogressive simplex lap winding is one in which the current in the coil terminates in the bar counterclockwise adjacent to the starting bar.

Simplex progressive and retrogressive wave windings are shown in figure 7-25. Compare these with the lap windings shown in figure 7-24. When you have to identify armature windings, you might think it will be complicated. Use of an organized test procedure will enable you to distinguish the types.

Test Procedures

There are many armature testing techniques. One method is to use a low-reading ohmmeter to indicate variations in the resistance readings as the test probes are shifted around on the commutator. If a low-reading ohmmeter is not available, a milliammeter connected in series



111.3

Figure 7-23. — Meaning of coil pitch in armature winding.

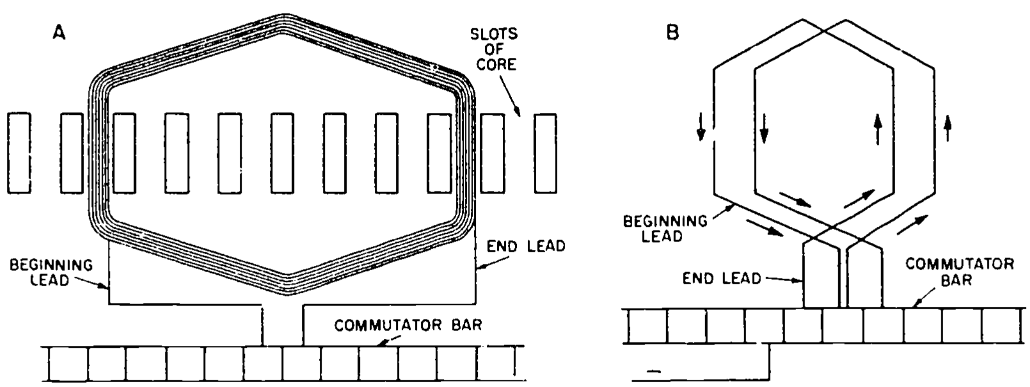


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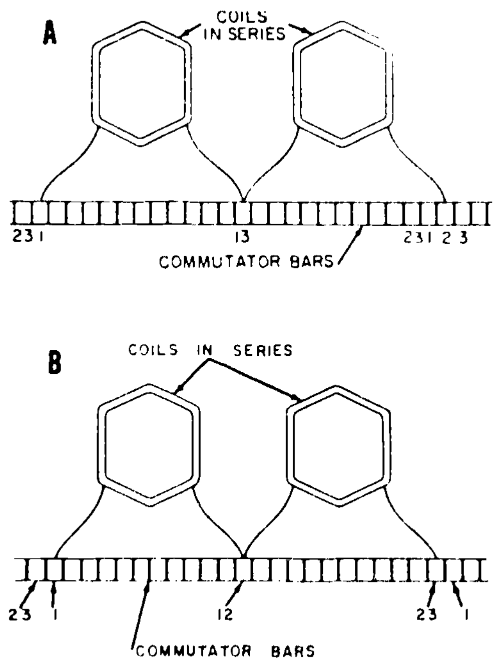
Figure 7-24. — Simplex lap windings. (A) Progressive; (B) Retrogressive.



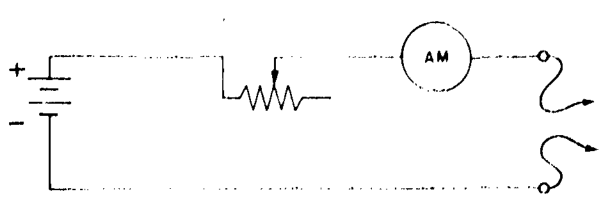
73.231
Figure 7-25. — Four-pole simplex wave windings. (A) Progressive; (B) Retrogressive.

with a rheostat and a 6-volt battery can be used (figure 7-26).

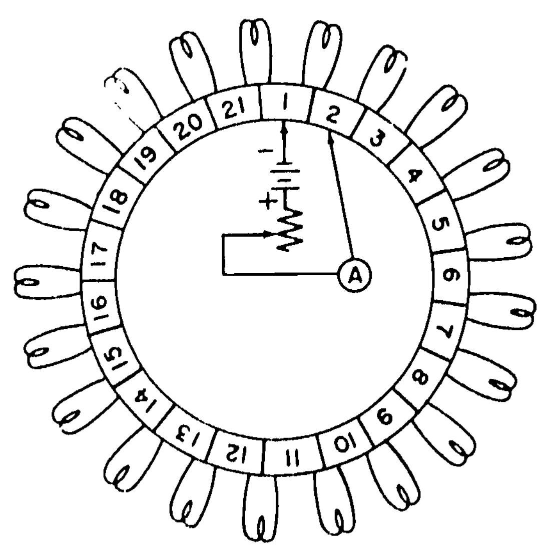
SIMPLEX LAP.—A schematic diagram of a simplex lap winding is illustrated in figure 7-27. With the test probes placed on adjacent segments, the ammeter will indicate a maximum because the resistance of only one coil shunts the remainder of the winding, and the resistance added to the test circuit is at minimum. Move one test probe to the next segment, and the ammeter reading decreases because the resistance between the probes has increased. With one probe stationary and the other probe contacting each segment in succession around the commutator, the armature indications will decrease steadily until the test probes are directly opposite each other, and then start increasing steadily as the other half of the winding is tested. These indications are obtained because of the method of connecting the coils to the commutator, which is determined by the type of winding. A simplex lap winding is the only winding that gives these indications.

SIMPLEX WAVE.—An important rule to remember for all wave windings is that the ends of each coil are connected to commutator segments that are approximately two pole pitches apart. Using the test procedure described previously, the maximum ammeter reading is indicated when the test probes are connected across that portion of the winding in which one coil shunts the remaining portion of the winding. Hence, in all wave windings the maximum reading will be indicated when the probes are placed on commutator segments that are approximately two pole pitches apart. The minimum ammeter reading will occur when the probes are placed on segments approximately one pole pitch apart.

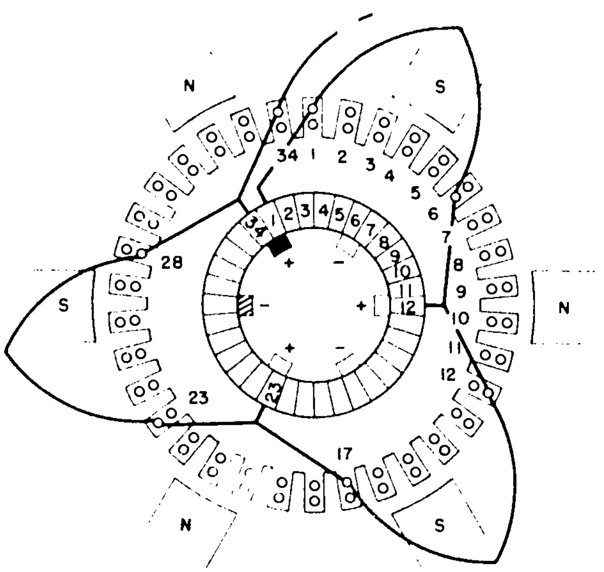
With one probe stationary on segment 1 (fig. 7-28) and the other probe moved around the



111.6
Figure 7-26. — Test circuit for measuring armature.



111.7
Figure 7-27. — Schematic of simplex lap winding.



111.12
Figure 7-28. — Portion of 6-pole, simplex wave winding.

commutator from segment to segment (2, 3, 4, and so forth), the ammeter readings steadily decrease until the probes are approximately one pole pitch apart, and then the readings steadily increase until the probes are approximately two pole pitches apart.

If the probe is circled around the remainder of the commutator, the readings will decrease and then increase once for each pair of poles. In the identification of a 6-pole, simplex wave winding there will be three successive decreases and increases in the meter readings as the commutator is circled once. Similarly, in a 4-pole simplex wave winding there will be two successive decreases and increases in the meter readings. Thus, a simplex wave winding can be readily distinguished from a simplex lap winding by measuring the resistances of the armature coils.

Trouble Indications

Some armature troubles may be detected while making inspections of running machines. Heat and the odor of burning insulation may indicate a short-circuited armature coil. In a coil that has some turns shorted, the resistance of one turn of the coil will be very low, and the voltage generated in that turn will cause a high-current flow, resulting in excessive heating, which will cause the insulation to burn. If the armature is readily accessible, the short-circuited coil can be detected immediately after stopping the machine because the shorted coil will be much hotter than the others. In idle machines, a short-circuited coil may be identified by the presence of charred insulation.

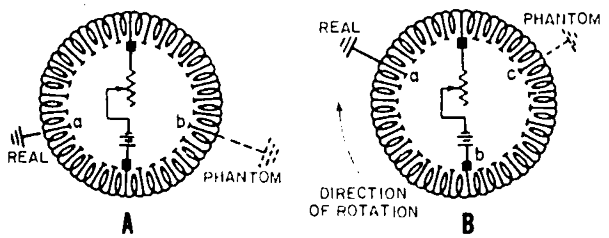
An open armature coil in a running machine is indicated by a bright spark, which appears to pass completely around the commutator. When the segment to which the coil is connected passes under the brushes, the brushes momentarily complete the circuit; when the segment leaves the brushes, the circuit is broken, causing a spark to jump the gap. Eventually, it will definitely locate itself by scarring the commutator segment to which one end of the open coil is connected.

When a ground occurs in an armature coil of a running machine, it will cause voltage fluctuation as the grounded coil segment passes from brush to brush during rotation of the armature. Two grounded coils result in the same effect as a short circuit across a group of coils. Overheating will occur in all of the coils in the group and burn out the winding. Grounded coils in idle machines can be detected by measuring insulation resistance. A megger, or similar insulation measuring device, can be connected to the commutator and to the shaft or frame of the machine in order to properly measure the resistance of the insulation of the coils.

Locating Troubles

Usually d-c armature troubles are confined to one coil or group of coils, and if not readily apparent, the segments to which they are connected can be located by a bar-to-bar test or use of a growler.

BAR-TO-BAR TEST. — A low voltage, d-c source, such as a storage battery, lighting circuit, or welding set, is required for this test. The machine must be disconnected from its normal power supply before the test is made and all except one pair of brushes lifted from the commutator. The voltage is applied across the

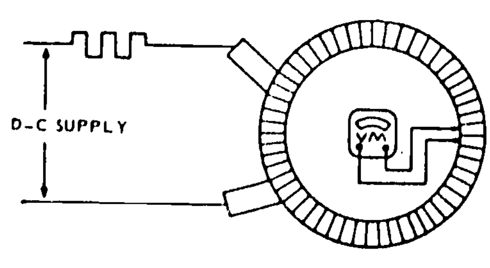


77.75
Figure 7-29. —Real and phantom grounds in bar-to-bar test.

+ and - brush through a resistance, lamp, lamp bank, or rheostat. A low-reading voltmeter or millivoltmeter is necessary for taking measurements.

To locate a ground in a d-c armature coil, one lead of the voltmeter is connected to the shaft, and, with the armature in a fixed position, the other lead is touched to each commutator bar in turn. If there is a ground, two or more bars will indicate practically zero readings. Some of these will be real and others will be phantom grounds (fig. 7-29, view A). All such bars should be marked with chalk. The armature is then rotated a few degrees and tested again. The real grounds will remain in the same bars while the phantom ones will shift to other bars. For example, in view B of figure 7-29, the phantom ground has shifted from bar b to bar c, while the real ground has remained in bar a. The ground will be in a coil connected to the bar, showing a real ground with the lowest voltage reading.

To locate an open or short circuit in a d-c armature, remove all brushes except those of one positive brush holder and an adjacent negative brush holder. Connect the low-voltage potential to these brushes and adjust the current, if need be, so that the readings obtained with the millivoltmeter will be roughly one-third to one-half full scale. The current must not exceed one-fourth that normally carried by one set of brushes. The voltage drop between two adjacent commutator bars is measured with a millivoltmeter. The armature is held in a fixed position, and the meter leads are moved from one pair of adjacent bars to the next until a test has been made of all the pairs of bars included between the brushes (fig. 7-30). The armature is then turned to bring different bars between the brushes, and these bars are tested. This is repeated as necessary to test all around the commutator. In a simplex winding, an open coil is located where the meter reading is a maximum, and a shorted coil where the reading is a minimum.



77.76
Figure 7-30. —Testing for an open coil.

For most armatures the windings will be free from fault if all the voltage readings are a small fraction of the voltage between the brushes and are equal within the limits of measurement. However, in some cases, a duplex winding may be encountered. This type of winding is indicated when the readings are only a small fraction of the voltage between the brushes and follow each other in a regularly repeating pattern such as O, R, O,R,O,R, and so on, where R is a reading different from zero. When this happens, a further test must be made by measuring the voltage drop between alternate bars— 1 and 3, 2 and 4, 3 and 5, 4 and 6, and so on. If these readings are equal within the limits of measurement, the winding will be free from faults.

When an open circuit is present, the voltmeter reading across one pair of adjacent bars will be approximately equal to the voltage between the brushes, and zero readings will be obtained on several pairs of bars on each side of the pair with the high reading. The open-circuited coil will be connected to one or both of the bars in the pair with the high reading. Should the voltmeter readings taken between adjacent pairs of bars increase or decrease in magnitude and be alternately plus and minus, a duplex winding is indicated. A further test by measuring the voltage drop between alternate bars is then necessary to locate the open circuit. When a reading approximating the voltage between the brushes is thus obtained, the open-circuited coil will be connected to one or both of the bars in the pair with the high reading.

When a short circuit is present, the interpretation of the indication given by readings between adjacent bars or between alternate bars (duplex windings) depends upon whether the armature has a lap or a wave winding. In an armature having a lap winding, a voltmeter reading considerably lower than the others will indicate a short-circuited coil is connected between the pair of bars that shows the low reading. A short-circuited coil in an armature with a wave winding will cause low readings to be obtained on as many pairs of bars as there are pairs of poles, and the short circuit will be in a coil connected to bars in these pairs.

The best method for locating the ends of a faulty coil in a wave-wound armature is to separate the coil from the rest of the winding in the following manner. In a 6-pole machine, a short-circuited coil in a wave-wound armature would be indicated at three positions during the test. These positions should be marked with chalk. When the riser connections on these segments are lifted, six coils will be isolated from each other and the rest of the winding. The shorted coil is located by comparing the resistances of the six coils, and it will have less resistance than the others.

GROWLER TESTS.—A growler (fig. 7-31) can be used to detect and locate grounds, opens and shorts in small armatures. The device consists of a coil of wire wound around an H-shaped, laminated iron core. The laminations on top are cut out to hold the armature under test between the two poles of the growler. When an alternating current is applied to the coil, an emf will be induced in the armature coils by transformer action.

To test an armature for grounds with the growler, place the armature on the poles of the growler and energize the coil from a 115-volt source. Connect one lead of an a-c millivoltmeter to the armature shaft and use the other lead as a probe, contacting each commutator segment one at a time in sequence (fig. 7-31, view A). If there are no grounds in the winding, no reading will be indicated on the meter because the commutator is insulated from the shaft. If there is a ground in the winding, a reading will be indicated on the meter for all good coils (view B of fig. 7-31). No reading on the meter indicates that the grounded coil is connected to this segment.

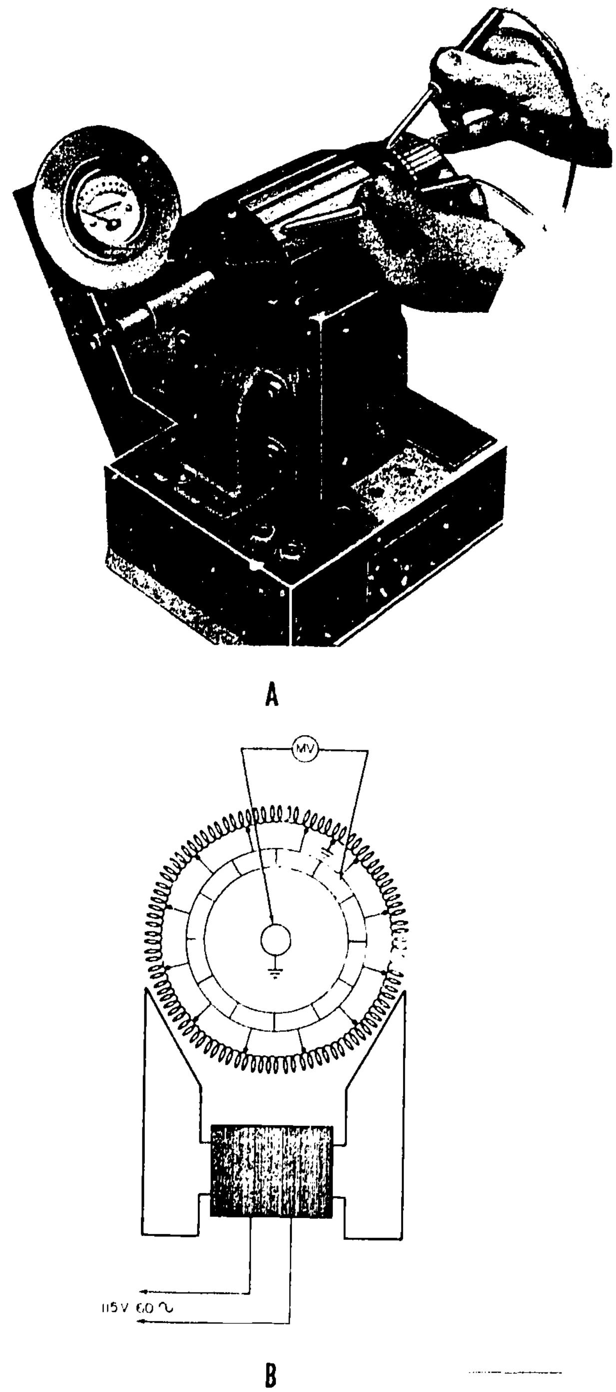


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Figure 7-31.—Growler.

To test an armature for shorted coils with the growler, place the armature on the growler and turn on the current. Hold a hacksaw blade directly over, and along the length of, the top slot. If the coil in this slot is shorted, the blade will vibrate rapidly and cause a growling noise. If the blade does not vibrate, it is an indication that no short exists in the coil. Test each slot in sequence by turning the armature so that the slot to be tested is on top.

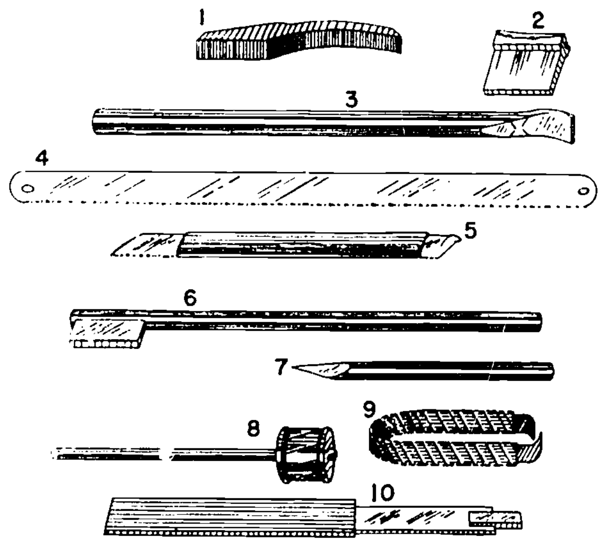
To test a simplex lap or wave armature for opens with the growler, set up the armature on the growler in the usual manner. Test the top two adjacent segments with an a-c millivoltmeter. Turn the armature and continue testing the two top adjacent segments. A reading will be indicated on the meter of all segments that are connected to good coils. No reading on the meter indicates an open coil between the two segments.

Emergency Repairs

Emergency repairs can be effected by cutting out a short-circuited or open-circuited armature coil. This will permit restoration of the machine to service until permanent repairs can be made. However, permanent repairs should be made as soon as possible. The coil is cut out by disconnecting both ends of the coil and installing a jumper between the two risers from which the coil was disconnected. The coil itself is then cut at both the front and rear of the armature to prevent overheating of the damaged coil. A continuity test from one end to the back of the coil will locate the turns of the faulty coil. If a pin or needle is used to puncture the insulation for this test, insulating varnish can be used to fill the tiny hole in the event the wrong coil is pierced. All conducting surfaces exposed by the change in connections should be insulated and all loose ends should be tied securely to prevent vibration.

Handtools

The handtools used in rewinding armatures are relatively few and simple. In fact, they are usually handmade by Construction Electricians engaged in this work. Figure 7-32 shows the following tools:



1. Fiber horn
2. Steel slot drift or tamping tool
3. Lead lifter
4. Hacksaw blades
5. Saw
6. Wedge driver
7. Lead drift
8. Rotation indicator
9. Wire scraper
10. Wedge inserter

111.17
Figure 7-32.—Armature rewinding handtools.

1. Fiber horn for shaping the coil ends after the coils are placed in the slots.

2. Steel slot drift, or tamping tool, for driving the coils to the bottom of partly closed slots.

3. Lead lifter for lifting the coil leads from the commutator risers.

4. Hacksaw blades for removing the fiber wedges that hold the coils in the slots.

5. Saw for undercutting the commutator mica between the segments.

6. Wedge driver for driving the fiber wedges out of the slots.

7. Lead drift for cutting off the leads at the risers.

8. Rotation indicator as an aid to determine the proper connections of the windings.

9. Wire scraper for removing the insulation from the ends of the coil leads.

10. Wedge inserter for driving the wedges into partly closed slots.

Stripping

Before stripping an armature, record all available winding data on an armature data card, as shown in figure 7-33, for use in rewinding and for future reference.

After recording the initial winding data, perform a bar-to-bar test to determine if the winding is lap or wave and record this information on the armature data card and proceed to disconnect and remove the coils.

During this process, accumulate the winding data that was impossible to obtain before stripping the armature. Remove the banding wires by filing them in two places. If banding wires are not used, remove the wedges in the slots. A simple means of removing the wedges is to place a hacksaw blade, with the teeth down, on the wedge. Tap the top of the blade to set the teeth in the wedge and then drive out the wedge by tapping the end of the blade.

Next, unsolder the coil leads from the commutator and raise the top sides of the coils the distance of a coil throw (distance between the two halves of a coil). The bottom side of a coil is now accessible, and the other coils can be removed one after the other. Exercise care to preserve at least one of the coils in its original shape for use as a guide in forming in the new coils. Next, record the wire size, number of turns in a coil, and type of insulation on the coils and in the slots.

To raise the coils without damaging the insulation, use a small block of wood as a fulcrum resting on the armature core and a steel bar or piece of wood as a lever.

KW HP	RPM	Volts	Amps
Cycle	Type	Frame	Style
Temp	Model	Serial	Phase

No of Slots	Bars	Coils/Slot
Size Wire	Coil Pitch	
Center of Slot to	Center of Bars Center of Mica	
Commutator Pitch Lap	Wave	

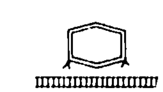


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Figure 7-33. — A d-c armature data card.

After the coil is partly raised, drive a tapered fiber wedge between the top and bottom coils within the slot to finish raising the top coil from the slot. After stripping the armature, remove all dirt, grease, rust, and scale by sand blasting. File each slot to remove any burrs or slivers and clean the core thoroughly with compressed air. Immerse the cleaned armature core in a varnish and bake in accordance with the steps in table 7-1, using a dilute varnish (20 percent solution) of the same type of varnish to be used after winding.

This treatment prevents the formation of oxides and forms a base for the adherence of the final varnish treatment.

Winding Armature Coils

Formed coils are wound on a coil-winding machine and pulled into the desired shape on the forming machine. The shape of the coil is determined by the old coil. The two wires forming the leads are taped with cotton or reinforced mica tape. The binder insulation, consisting of cotton or glass tape, is applied to the entire coil surface.

The coil is now sprayed with a clear air-drying varnish (grade CA), which conforms to Military Specification, MIL-V-1137. After the varnish has dried, the coil ends are tinned to ensure a good connection to the commutator.

Preformed windings should be used on large armatures, but it is more practical to wind small armatures by hand. End room is very limited, and windings must be drawn up tightly to the armature core. Figure 7-34 shows the method of winding an armature by hand. One armature in the figure is small enough to be hand-held. The other, too heavy for this, rests on a support.

Placing Coils in Slots

Before assembling the coils insulate the armature core. This step is of extreme importance; if the armature contacts the coils, you will have to do your work over. Clean the core slots and ends, and true up the laminations. Use fish paper or fuller board for insulation, and let it extend 1/4 in. beyond the slots, to prevent the edges of the laminations from

Table 7-1. — Varnishing procedure

Typical treating schedule.— The following treating schedule may be used as a guide in processing electrical windings. The baking time and temperature may vary depending on the type and grade of varnish used and the size of the winding being processed:

Armature coils, armatures, stators and field coils

	Class A, Class B and Class F systems	Class H and higher temperature systems
Step 1: Prebaking	Put into oven at 110°C (230°F). Hold at temperature for 4 hours. Cool to approximately 50°C (122°F).	Put into oven at 150°C (302°F). Raise temperature 50°C (122°F) per hour to a maximum of 200°C (392°F). Hold at temperature for 4 hours. Cool to approximately 50°C (122°F).
Step 2: Dipping	Immerse coils or wound apparatus in 40°C (104°F) in varnish until bubbling ceases. Viscosity shall be held between 150 to 250 centipoises. Thin Class A, Class B varnish with mineral spirits to maintain viscosity. Use xylene for Class F varnish.	Immerse coils or wound apparatus in varnish for not over 5 minutes. Varnish types or grades shall not be mixed. Viscosity shall be held between 125 to 225 centipoises. Thin with xylene to maintain viscosity.
Step 3: Draining	Drain and air dry for 1 hour. Rotate wound apparatus to prevent pocketing the varnish.	Drain and air dry for 1 hour. Rotate wound apparatus to prevent pocketing the varnish.
Step 4: Wiping	After draining but before baking the metal surfaces of the armature, the bore of the stator and the pole faces of the field structure must be wiped with a cloth moistened with solvent.	After draining but before baking the metal surfaces of the armature, the bore of the stator and the pole faces of the field structure must be wiped with a cloth moistened with solvent.
Step 5: Baking	Bake in a circulating type, forced-exhaust, baking oven at temperature of 150°C (302°F) for 6 to 8 hours.	Put into a circulating type, forced-exhaust, baking oven at temperature of 200°C (392°F) for 2 hours.
Step 6: Cooling	Remove from oven and cool to approximately 50°C (122°F).	Remove from oven and cool to approximately 50°C (122°F).
Step 7: Second treatment (dip in opposite direction).	Repeat steps 2 (immerse for 1 minute), 3, 4, 5, and 6.	Repeat steps 2 (immerse for 1 minute), 3, 4, 5, and 6.
Step 8: Third treatment (dip in original direction).	Repeat steps 2 (immerse for 1 minute), 3, 5, and 6.	Repeat steps 2 (immerse for 1 minute), 3, 5 (baking additional 8 hours at 230°C (446°F)) and 6.

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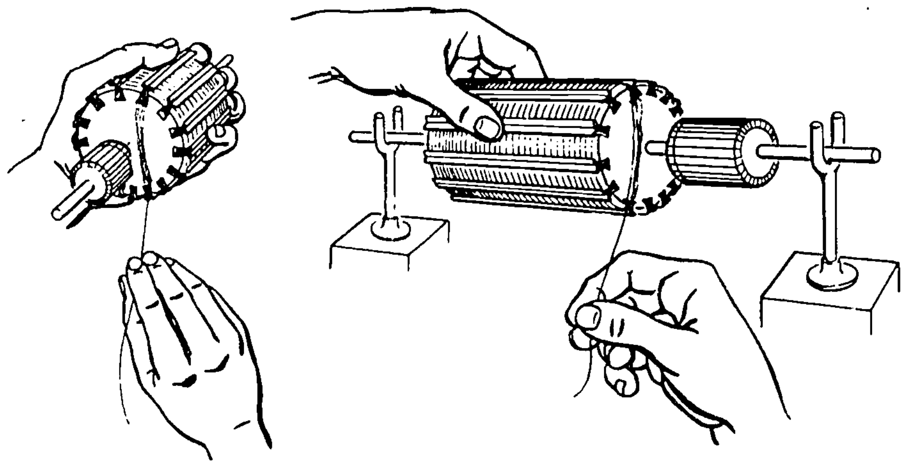

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Figure 7-34. — Winding armatures by hand.

injuring the coils. Figure 7-35 shows a method of insulating the slots.

The ground insulation, consisting of flexible mica wrappers or layers of reinforced mica tape, is applied to the coil sides that lie in the slots. The formed coils are next placed in the slots, the lower side first and then the upper side, until all the coils are inserted and the winding is completed. Be certain that the coil pitch is correct. A strip of rigid laminate, type GME-MIL-P-15037, is placed in each slot between the lower and upper coil sides, and a similar strip is placed at the back and front of the armature where top and bottom sides cross each other. If the slots have straight sides, they are filled up with a strip of rigid laminate, type GME-MIL-P-15037, on the tops of the coils so that they can be held down by the banding wires. In some armatures the slots are shaped so that fiber wedges can be driven in each slot from one end to hold the coils in place.

Before soldering the coil ends to the commutator segments, test the winding for grounds, opens, shorts, and dead coils. Exercise care (when soldering) to prevent solder from falling or running down the back of the commutator, as this would result in a short circuit. Tip the armature so that the solder will not flow down the back of the commutator. Place the tip of the soldering iron on the commutator near th riser and wait until the iron heats the riser sufficiently to melt the solder. Touch the solder to the riser and allow it to flow down and around the lead and into the wire slot, and then remove the iron.

The ordinary soldering iron cannot supply sufficient heat fast enough to perform a satisfactory soldering job on a large armature. Therefore, apply a soft flame from an acetylene torch to the outside end of the commutator segments to the riser ends where connections are made. Tin the coil ends (to be connected to the commutator risers) with the soldering iron. Next, tin the slots in the commutator risers

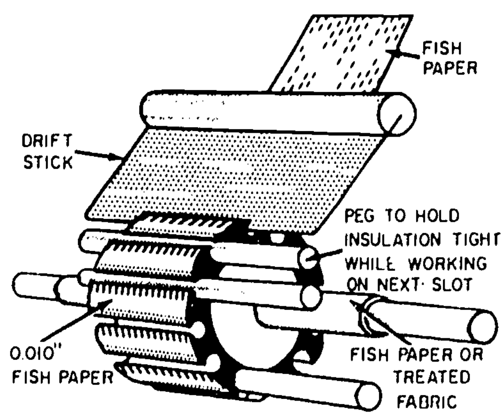

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Figure 7-35. — Continuous strip method of insulating slots.

with heat from the torch. Then make the connections while applying the flame to the outside end of the commutator segments. Wrap the winding in asbestos tape for protection (when making the commutator connections) because too much heat can damage the winding insulation. The completed armature winding is checked electrically for continuity and for shorted turns.

To prevent centrifugal force from throwing the coils outward, wind a band of high-grade steel piano wire on a strip of leatheroid, which is placed around the armature and over the coils about 2 inches from the edge of the core. This is done either before or after the armature has been dipped and baked.

It is preferable to place the banding wires on the armature while the windings are hot because the insulation shrinks when heated, is more flexible, and can be pulled down tightly much easier than when the armature is cold. When the first banding wire is wound on the armature, small tin clips, with insulation under them, are inserted under the wire. When the required number of turns has been applied, the ends of these clips are turned up over the wires to hold them tightly side by side. The clips are then soldered with a tin solder, and a thin coat of solder is run over the entire band to secure the wires together.

The end windings are secured, if necessary, by groups of wire wound on insulating hoods to protect the coils. On the commutator end, strips of thin mica with overlapping ends are usually placed on the commutator neck and held by a few turns of cord. On large armatures, banding wires are sometimes placed over the laminated portion of the armature. The laminations on these armatures have notches in which the banding wire is placed.

If it is necessary to rebuild a commutator, use molding micanite to insulate between the spider and the commutator. Commutator mica is used as insulation between the segments. After the commutator is assembled, it is heated and tightened with a clamping ring.

If shrink rings are provided, they are not put on until the commutator has been tightened (while hot) and the banding wires tightly placed around it. If defective, small commutators are usually completely replaced.

Insulating Materials

Current-carrying conductors require insulation for various reasons. An understanding of the different types of insulation used will be of help to you in the repair of electrical equipment. The different classes of insulation materials are listed in table 7-2.

There are certain conditions when the rewinding of Class A and B insulated motors with Class H insulation becomes necessary. This is done to prevent a recurrence of insulation breakdown and ultimate failure. Here are examples of such conditions:

1. Where the location ambient exceeds the equipment design ambient (usually 50° C).

2. Where excessive moisture (usually condensate) is present and the windings are exposed.

3. Where the service life of existing equipment is shortened by overload, heat, moisture, or a combination of these factors.

Silicone insulation is not a cure-all for motor and generator failures. Before deciding to use silicone insulation the installation should be checked to determine the cause of failure. Misalignment of bearings, mounting bolts dislocated, a bent shaft, failure or inoperativeness of overload devices or similar causes may have initiated the failure rather than the insulation itself.

Consideration must be given to the conditions to which the windings will be subjected during winding, varnishing, and drying out or baking. Class A, B, and F materials are generally tough and will take a lot of abuse. Class H and N materials are considered somewhat fragile and should be handled with care in order not to damage the resin film.

Varnishing

Prior to varnish treating, the windings or coils should be prebaked to remove all moisture. The windings or coils should be left to cool to a temperature not less than 10° C above room temperature prior to immersion in varnish. The windings or coils should remain in the varnish

Table 7-2. — Classes of insulation

CLASS INSULATION SYSTEM	CLASS MATERIAL	MATERIALS OR COMBINATION OF MATERIALS	REQUIRED THERMAL LIFE
A	105	Cotton, silk, and paper when suitably impregnated or coated, or when immersed in a dielectric liquid such as oil.	105°C
B	130	Mica, glass fiber, asbestos, etc., with suitable bonding substances.	130°C
F	155	Mica, glass fiber, asbestos, etc., with suitable bonding substances.	155°C
H	180	Silicone elastomer, mica, glass fiber, asbestos, etc., with suitable bonding substances such as appropriate silicone resins.	180°C
N	200	Mica, glass fiber, asbestos, etc., with suitable bonding substances.	200°C

11.132

until bubbling ceases. After dipping, the windings or coils should be allowed to drain and then are baked at the prescribed temperature for the time shown in table 7-2. Do not dip and bake more than three times. The baking ovens must be rated at 350° F for Class A, B, and F windings and 500° F for higher temperature windings and must be of sufficient capacity to maintain these temperatures at a full exhaust rate of two air changes per minute.

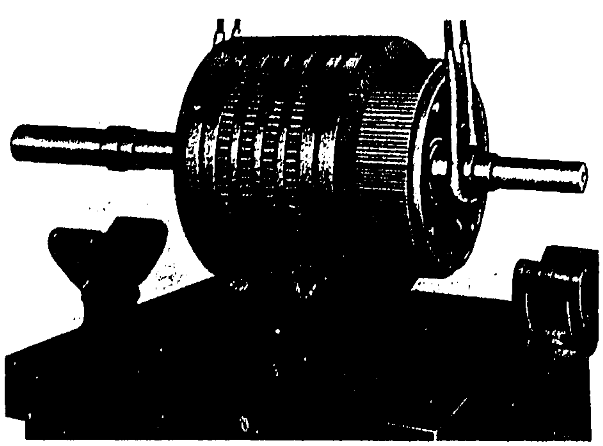

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Figure 7-36. —Applying insulating varnish to armature windings.

Separate dip and storage tanks should be provided for the silicone varnish, because silicone varnish is not compatible with other varnishes. No solder joints should be used on the tanks as solder may gel the varnish.

The d-c armatures should be dipped with the commutator end down to seal behind the commutator neck. The commutator can be wrapped to prevent varnish buildup. When draining, have the commutator upright. If the assembled winding cannot be immersed, it can be slowly rotated in a horizontal position in a shallow pan to allow the varnish to flow into the winding interstices (fig. 7-36). All winding parts should be well soaked during the immersion. At least two complete revolutions should be made, each revolution taking about 10 minutes. In the baking operation allowances should be made for the time necessary to bring the armature up to temperature. If possible, d-c armatures should be baked with the commutator end up.

The completed armature is now placed in a lathe and a very light cut taken over the surface of the commutator and over the face and side of the commutator risers to make the assembly perfectly true. Next, the commutator mica should be undercut so that the carbon brushes will not be damaged by the high mica.

You must remember that all armature stator and field windings must be checked for shorts, grounds, and opens after each step of being wound, formed, taped (if necessary), installed, connected, dipped, and baked.

High-Potential Tests

A high-potential test is made by applying (between insulated parts) a test potential that is higher than the rated operating voltage. High-potential tests are frequently used in connection with the repair or reconditioning of naval equipment ashore.

The purpose of the test is to break down the insulation if it is weak, thereby indicating defective material and workmanship, and permitting replacement prior to actual use.

The application of each high-potential test tends to weaken insulation even though it does not produce actual failure at the time. Also, the use of high-potential tests requires special equipment and safety precautions.

When making high-potential tests on electrical equipment that has been reconditioned or rewound in a shop, keep from coming in contact with any part of the circuit or apparatus. Never touch the winding after a high-potential test has been made until it has been connected to ground to remove any static charge it may have retained.

A high-potential test should not be made on a d-c generator or motor until after the reconditioning or rewinding is completed, including the application of varnish, and the insulation resistance has been measured and found to be higher than the value in the last column of table 7-3.

All leads to the circuit being tested should be connected to one terminal of the source of test voltage. All leads to all other circuits and all metal parts should be connected to ground. No leads are to be left unconnected for a high-potential test as this may cause an extremely severe strain, at some point of the winding. For example, to make a high-potential test on a rewound armature, short circuit the commutator segments by wrapping one or more turns of bare wire around the commutator and apply the high-potential test voltage across the common connection of all the commutator segments and the grounded armature shaft.

The high-potential test voltage is obtained from a 60-hertz a-c source that should have a capacity of 1 kilowatt. When making a test, increase the voltage as rapidly as possible without exceeding the correct value, as indicated on

Table 7-3.—Minimum Direct-Current Generator and Motor Insulation Resistances for High-Potential Tests

Circuit	Insulation Resistance in Megohms at 25°C,[1] After Reconditioning in Shop.
Complete armature circuit[2]	1
Armature alone	2
Armature circuit less armature[2]	2
Complete shunt field circuit[2]	2.5

[1]The figures given are for machines rated at 250 volts or less. For machines having a rated voltage, E, greater than 250 volts, multiply all figures given in the table by E/250.

[2]Small machines usually have one of the shunt field leads connected internally to the armature circuit. To avoid disassembly in such cases, the complete armature circuit and complete shunt field circuit may be measured without breaking this connection. If necessary, the armature can then be isolated by lifting all brushes.

(a) With the brushes left in place, the complete armature circuit will include armature, armature circuit, and the permanently connected shunt field circuit. The values given in the table for the complete armature circuit will apply.

(b) With the brushes lifted, the armature circuit less armature and the complete shunt field circuit will be measured. The values given in the table for armature circuit less armature will apply.

111.83

the voltmeter. The full voltage should be maintained for 1 minute. The voltage should then be reduced at a rate that will bring it to one-quarter of the corre value or less in not more than 15 seconds.

FIELD COILS

Preventive maintenance of field coils requires periodic inspections and tests to determine the condition of the coil. Coils should be cleaned periodically to remove any foreign particles which might have collected on them.

The insulation on field coils should be tested periodically to determine its condition. A resistance-measuring device may be used for this purpose. If a ground is detected in the field circuits (shunt, series, and interpole) of a d-c machine, the circuits must be disconnected from each other and tested separately to locate the grounded circuit. Then all the coils in that circuit must be opened and tested separately to locate the grounded coil, which can be repaired or replaced as necessary.

If an open circuit develops in the field windings of an a-c or d-c generator that is carrying a load, it will be indicated by immediate loss of load and voltage. An open in the shunt field winding of an operating d-c motor may be indicated by an increase in motor speed, excessive armature current, heavy sparking, or stalling of the motor. When an open occurs in the field circuit of a machine, it must be secured immediately and examined to locate the faulty circuit. The open circuit will usually occur at the connections between the coils and can be detected by visual inspection. An open in the coils generally causes enough damage to permit detection by visual inspection.

Rewinding Field Coils

The old field coil is removed from the pole piece and, if spare coils are available, a new one is installed. If a new coil must be made, record all pertinent coil data as the old coil is stripped down.

This data should include the (1) dimensions of the coil, both with the tape on and with the tape removed, (2) weight of the coil without the tape, (3) size of wire, and (4) type of insulation.

The two general classes of coils are (1) shunt field coils, which consist of many turns of fine wire and (2) series and commutating field coils, which consist of fewer turns of heavy wire.

SHUNT COILS. — The equipment for rewinding shunt coils includes a lathe or suitable face plate, which can be turned at any desired speed, and an adequate supply of the proper size wire wound on a spool, which can be supported on a shaft so that it is free to turn. Friction should be applied to the spool to provide tension on the wire. A coil form having the exact inside dimensions of the coil is secured to the lathe or face plate. The form for shaped field coils can be made from a block of wood shaped exactly to the required size and provided with flanged ends to hold the wire in place (fig. 7-37). One of the flanges should be removable so that the finished coil can be taken from the forming block.

The wire is now wound from the spool onto the forming block for the required number of turns. The turns must be evenly spaced, one against the other, until the winding procedure is completed. The turns of the completed coil are secured by tape, and the wire leading to the spool is cut, leaving sufficient length to make the external connections. The completed coil must be checked electrically for continuity and for shorted turns.

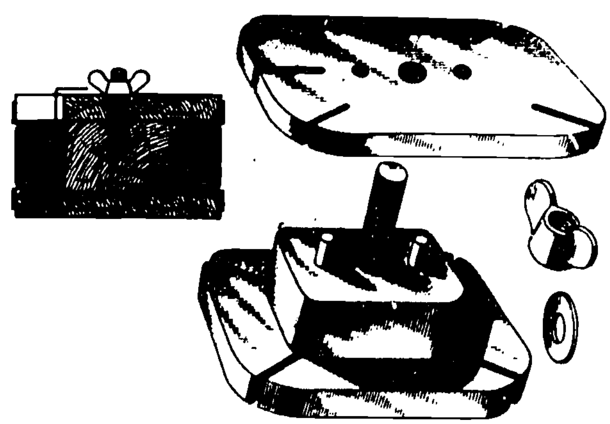

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Figure 7-37.— Coil form for field coils.

The coil is now prebaked and varnish treated. When varnish treated, the finished field coil should withstand a high-potential test of twice the rated excitation voltage +1,000 volts.

SERIES AND COMMUTATING COILS. — Series and commutating field coils are frequently wound with strap (rectangular) or ribbon copper instead of round wire. These coils have only a few turns that are wound in a single turn per layer.

A series coil wound (with ribbon copper) on edge is illustrated in figure 7-38. It is more difficult to bend the copper ribbon, but it has an advantage in that both terminal leads protrude on opposite sides of the coil. Thus, the connections can be made very easily compared to the strap-wound coils, which have one coil end at the center and the other coil end at the outside of the coil. The strap-wound construction requires leading the inside coil end over the turns of strap in the coil.

After the winding is completed, the coil is tested electrically for continuity and shorted turns. It is then prebaked, varnished, and tested for polarity, grounds, opens, and shorts as described previously, at each stage in turn.

Compass Aids

Before installing a new or repaired coil, it should be tested for shorts, opens, and grounds and its polarity determined. A small magnetic compass may be used to determine the polarity of a field coil by holding it several inches away from the coil along its axis (fig. 7-39). A small battery is connected to the coil leads, and if the south compass needle points toward the center of the coil, the face of the coil nearest the compass will be a north pole. This will indicate that the coil should be placed on a north pole in the same position it was in during the test, and the field current should flow through the coil in the same direction.

To protect the armature, the same precautions that were observed during removal of the coil must be observed when installing it. All of the shims originally removed from the pole piece must be in position when it is replaced. With the coil in position in the machine, it should be temporarily connected to the other coils in the field circuit and a compass and battery again used to check its polarity. For this test, connect the battery to the proper field leads and check the polarity of all the coils with the compass (fig. 7-39). Adjacent poles must be of opposite polarity. If need be, polarity of the new coil can be reversed by reversing its leads. When the polarity is correct, the coil is connected, and the pole-pieces bolts are tightened. Air gaps should be measured to ensure uniformity.

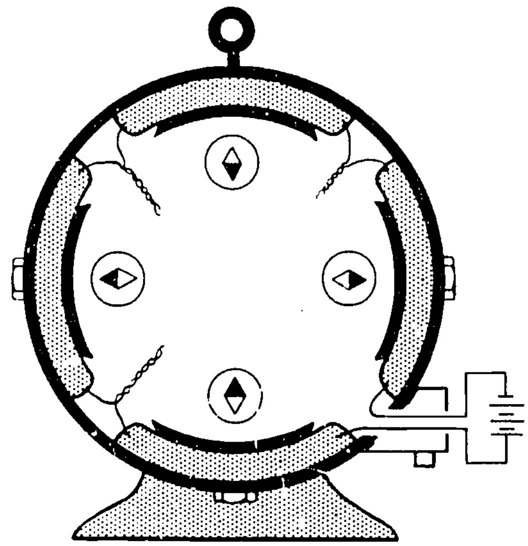

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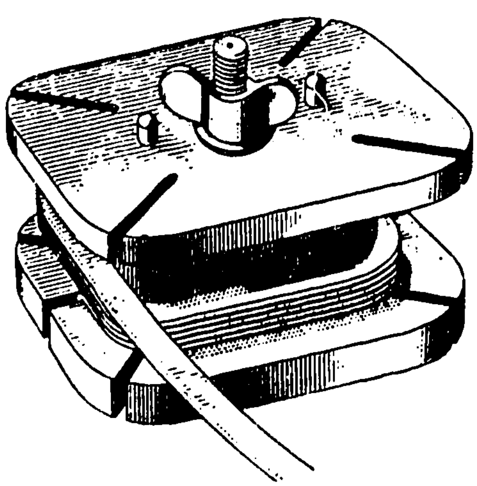
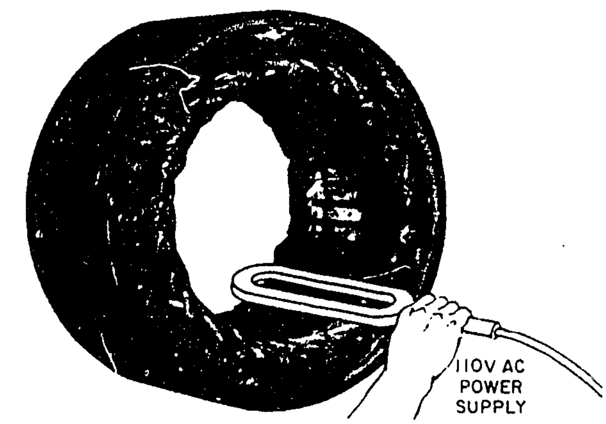
Figure 7-39. — Testing polarity of field coils.



77.84
Figure 7-38. — Edge-wound series coil.



73.147
Figure 7-40.—Testing a three-phase stator for shorted coils.

ALTERNATING-CURRENT STATOR COILS

Alternating-current stator windings require the same careful attention as other electrical windings. For a machine to function properly, the stator windings must be free from grounds, short circuits, and open circuits. Frequent tests and inspections are necessary to determine the condition of the windings, and they must be kept clean to preserve the insulation.

A short circuit in the stator of an a-c machine will produce smoke, flame, or the odor of charred insulation. The machine must be secured immediately.

Open circuits in a-c stator windings can sometimes be found by visual inspection because the open is usually the result of damaged connections where the coils and circuits are connected together. Should visual inspection fail, resistance measurements between the phase terminals will reveal the presence of open-circuited coils. The coil ends in the faulty phase are tested with an ohmmeter to locate the open-circuited coil. When the open circuit is in an inaccessible location and cannot be reached for repairs, the machine can be repaired for emergency use by cutting out the faulty coil.

Grounds in a-c stator windings can be detected with a megger or similar resistance-measuring instrument. Both ends of each phase are opened and tested to locate the grounded phase. Then, each circuit in the grounded phase is opened and tested to locate the grounded circuit. Finally, the ends of each coil in the grounded coil are located.

Shorted coils are identified readily if an internal growler is used. This instrument has an attached blade which is run over the stator coils (fig. 7-40). Transformer action causes a growling noise when a shorted coil exists.

It is most important to keep an accurate record of all the pertinent data concerning the winding on the stator data sheet, as shown in figure 7-41. If possible this information should be obtained before stripping; if not, it can be obtained during the stripping operation.

An a-c stator is stripped in the same manner as a d-c armature. Exercise care to preserve one coil in the original shape to provide the dimensions for the new coils if spare coils are not available and it is necessary to rewind them. Be certain to measure the end room of the coils before they are removed from the slots. Record this distance on the data sheet and be sure that the new coils do not extend beyond this distance from the ends of the slots. The winding should be preheated in an oven to soften the varnish and thus facilitate stripping. The end connections, preferably at the lead end, are then cut and the coils removed from the slots by pliers or a screwdriver.

After the stator is stripped, inspect the laminations for alignment and especially for sharp

Make

H.P.	R.P.M.	Volts	Amps.
Hertz	Type	Frame	Style
Temp.	Model	Serial	Phase

No. of Coils	No. of Slots	Connection
Size Wire	No. of Turns	No. of Groups
Coils/Group	No. of Poles	Pitch of Coil

111.65
Figure 7-41.—Stator data sheet.

burrs protruding from the end laminations. The stator should be cleaned of all dirt, grease, rust, and scale. The stator, similar to the d-c armature, is then varnish-dipped and baked, using a dilute varnish of the same type that is used after winding.

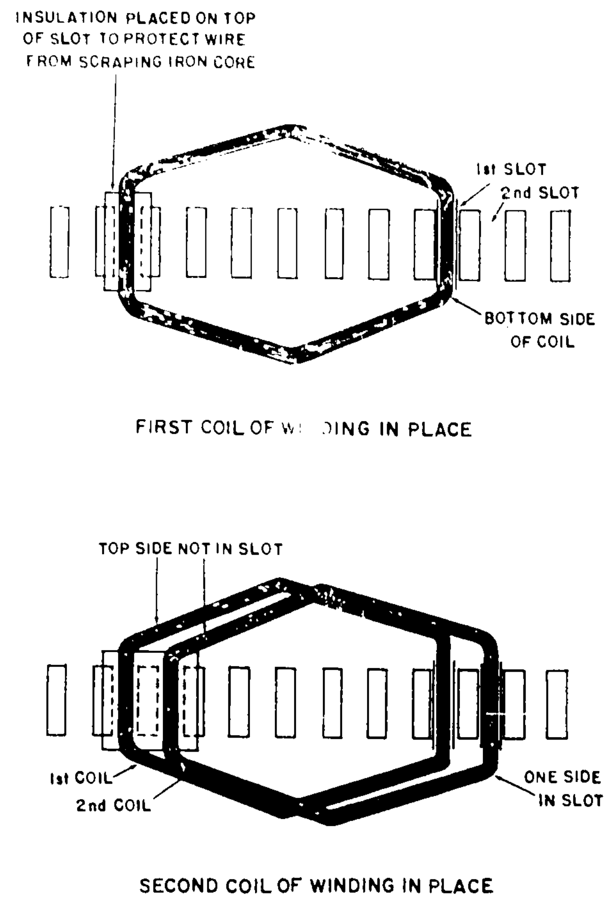
The windings of stator coils are usually prewound and preformed (formed coils) on a machine. The size and shape of the coils are best determined from the coil that was removed from the stator intact. After the coil is wound, it is tied in several places to hold the turns together. The two wires forming the leads are taped or sleeved with glass braided sleeving. The excess insulation is removed from the free ends of each coil, which are then tinned. The individual coils are then checked electrically for continuity and for shorted turns.

Placing Coils in Slots

The coils to be inserted in open slots have the entire surface taped, and the coil sides are placed in each slot intact. The right side of the coil, which occupies the bottom half of the slot, is inserted first (fig. 7-42). The free end coming from this side is known as the bottom lead of the coil. The left side of the coil, which occupies the top half of another slot, remains free. Continue by placing the right side of the second coil in slot 2 adjacent to slot 1. The remaining coils are inserted in this manner until the slots spanned by a complete coil pitch each contain the right side of a coil. The left side of each coil remains out of the slot until the bottom half of the slot is occupied by the right side of a coil. Continue around the stator, and then insert the left side of each coil on top of the right side of a coil several slots away, depending on the coil pitch.

Before inserting the side of the second coil in a slot, insulate it from the first coil's side already in the slot. This is done by placing a strip of insulation over the bottom coil.

Be certain that each coil side extends beyond the slot at both ends and does not press against the stator core at the corners. The phase insulation consisting of varnished cambric is placed between the phase groups because of the high voltage existing between phases. The computations indicated under interconnection of phases



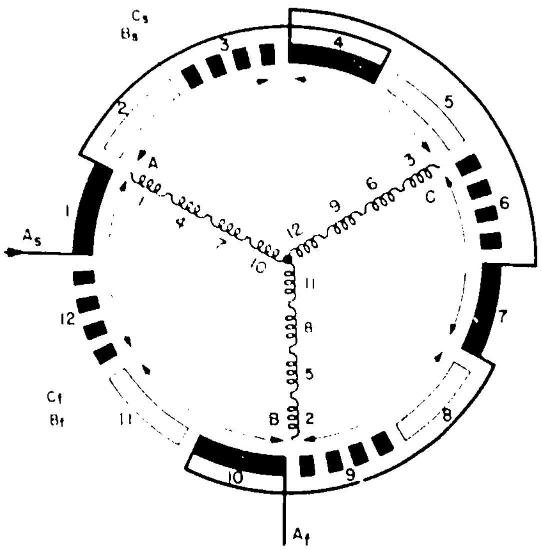
111.66

Figure 7-42. Placing coil sides in slots.

should be completed before any coils are inserted in the stator to allow for this extra insulation.

After the stator coils are all in place, force the coil sides down in the slots by placing a piece of soft wood or fiber on top of the coils through the slot opening, and gently tapping on it. When the coils are securely in the slots, insert the slot wedges to hold the coils in place. The wedges consist of flat melamine laminates machined to shape.

When all the coils have been inserted in the stator slots, the ends insulated, and the slot wedges driven in place, there will be two free ends for each coil (top and bottom) from one side of the stator wir   The free ends must



111.67

Figure 7-43. — Three-phase 4-pole winding for a 36-slot stator.

be connected to form a series of groups of coils.

You can compute the number of coils in a group by dividing the number of coils in the stator by the number of pole-phase groups. For example: if the stator has 36 slots and 36 coils, and if there are 4 poles and 3 phases, you will have 3 coils in series in each group. The number of poles multiplied by the number of phases gives the number of pole-phased groups.

To connect the pole-phase groups together, you should have a diagram similar to figure 7-43. Mark with arrows the direction of the current flow through each pole-phase group. The current flow must reverse in direction for each successive group so that there will be alternate north and south poles.

In arranging these coils into pole-phase groups, start by bending (forming) the inside lead of the first coil in toward the center and then connect the outside lead of that coil and the inside lead of the next coil together. Connect the outside lead of the last coil with the inside lead of the next coil and bend the outside lead of this coil away from the center. Repeat this procedure for each of the pole-phase groups all around the stator. Do not solder the connections at this time.

After twisting the ends together, check the individual groups to determine that the proper number of coils have been connected together in each pole-phase group and that they have the proper polarity. Then solder the twisted connections and cut off the ends so that the soldered stubs are about three-quarters of an inch long. Insulate the stubs with cotton tape or reinforced mica tape.

If the distance to the bearing brackets (frame of the machine) is small, bend the insulated stub in between the coils so that they do not come in contact with the frame when the stator is assembled in the machine.

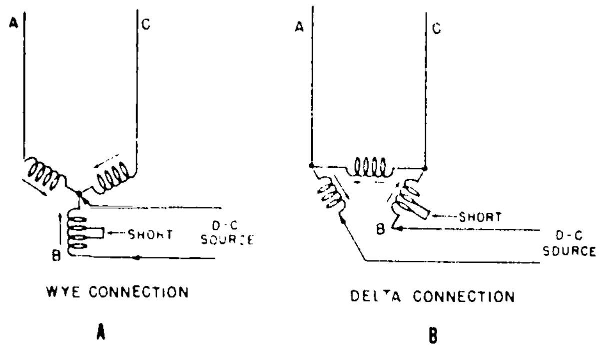
In practice, the coils that comprise the pole-phase groups are usually gang wound. Gang wound coils eliminate the need for stubbing, because the coils are wound with a continuous length of wire.

Polyphase Stator Troubles

In troubleshooting rewound and reconnected polyphase stator windings, you are likely to find that the trouble is a short in a pole-phase group or an entire phase, or that a winding is open circuited.

SHORTED POLE-PHASE GROUP. — An entire pole-phase group may be shorted in a polyphase stator. Such a defect is usually indicated by excessive heat in the defective part. The trouble can be readily located by a compass test. To conduct a compass test, excite the stator windings with a low-voltage, direct current that will set up the poles in the stator (fig. 7-44). When the windings are excited, a compass is moved around the inside circumference of the stator core. As each pole group is approached, the polarity is indicated by the compass. There should be the same number of alternate north and south poles in a 3-phase winding.

In a 3-phase, wye-connected winding (view A, fig. 7-44), test each phase separately by impressing the d-c voltage successively on each of the phase leads and the midpoint of the wye connection. If there is no trouble in the winding, the compass will indicate alternately north and south at each pole-phase group around the stator. If a complete pole-phase group is shorted, the compass needle will not be deflected at this point.



111.76
Figure 7-44.—Compass test for shorted pole-phase groups.

In testing a 3-phase delta-connected winding (view B of fig. 7-44), open one of the delta connections and apply the direct current to the winding. The current will flow through the three phases in series. If the pole-phase groups are connected properly, the compass will indicate alternate north and south poles around the stator frame. As in the wye-connected winding, a shorted pole-phase group is indicated by no deflection of the compass needle.

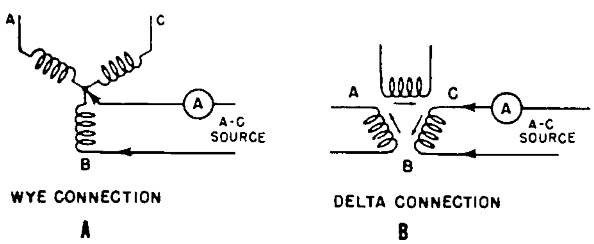
SHORTED PHASE.—When an entire phase of a 3-phase winding is shorted, the defect is most readily located by a balanced-current test made with an industrial analyzer.

This test can also be made with an ammeter and low-voltage a-c source. In testing a 3-phase wye-connected winding (fig. 7-45, view A), test each phase separately by impressing the a-c voltage successively on each of the phase leads and the midpoint of the wye connection. If there is no trouble in the windings, and if the impedance of the winding of each phase is the same, the ammeter will indicate approximately the same value of current for each of the three phases. If one phase is shorted, the ammeter will indicate a higher current reading for this phase than those of the other two phases because the impedance is less.

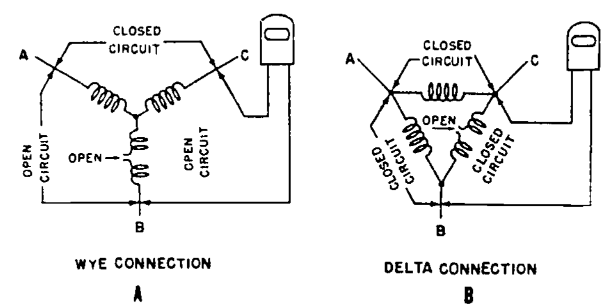
In testing a 3-phase delta-connected winding (fig. 7-45, view B), open each delta connection and test each phase separately. As in the wye-connected winding, the shorted phase will be indicated by a much higher current reading on the ammeter.

OPEN CIRCUITS.—An open circuit in a 3-phase winding can be readily located by means of an ohmmeter. In testing a 3-phase wye-connected winding (fig. 7-46, view A), connect the ohmmeter leads across each of the phases to locate the defective phase. When the ohmmeter leads are placed on terminals A and C, no open circuit (a low reading) is indicated. However, when the leads are placed on terminals C and B, and then on terminals B and A, an open circuit (a high reading) is indicated in both positions, thus denoting an open in phase B. After the defective phase has been located, test each stub connection of the pole-phase groups with the ohmmeter until the open coil is located.

In testing a 3-phase, delta-connected winding (fig. 7-46, view B), it is necessary to open one delta connection to avoid shunting the phase being tested. Test each phase separately until



111.77
Figure 7-45.—Balanced current test for shorted phase.



111.78
Figure 7-46.—Ohmmeter test for open circuits.

Single Phase ☐ Capacitor ☐ Split Phase ☐

H.P.	Hz	Type	Style
R.P.M.	Volts	Model	Ser. No.
Make	Amps	Frame	Cap MFD

Rotation facing shaft	Clockwise ☐ Counter-Clockwise ☐	No. Poles	No. Slots

Winding	No. Coils Per Pole	Turns Per Pole	Inside Coil Span	Size Wire	Type Wire	No. Circuits	Coil Extension	Stator Dimensions
								Inside Diameter
Running								Length of Core
Starting								Depth Iron Behind Slot

Running																		
Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Starting																		

111.65

Figure 7-47.—Single-phase motor data card.

the open is located. After the faulty phase is located, test each stub connection of the pole-phase groups, as in the wye-connection, until the open coil is located.

If the windings are parallel, it is necessary to open each parallel group and test each group separately.

MOTOR AND GENERATOR MAINTENANCE

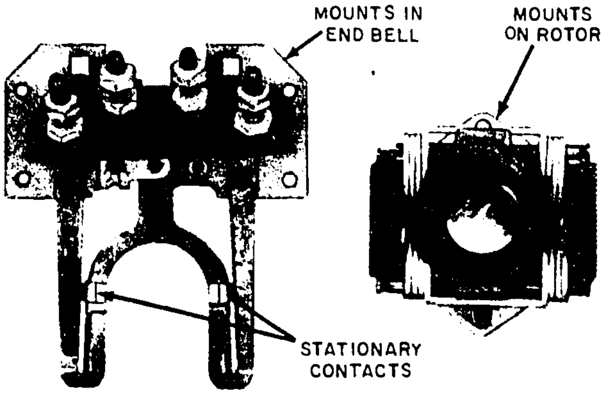
There are many applications for single-phase motors in the Navy. They are used in interior communication equipment, refrigerators, fans, drinking fountains, portable blowers, portable tools, and in many other applications. Single phase motors are considerably cheaper in fractional horsepower sizes, but above 1 horsepower the 3-phase motors are less expensive. The use of single-phase motors also eliminates the need of running three wire service to supply small loads.

In Basic Electricity, NAVPERS 10086-B, chapter 17, there is a section devoted to single-phase motors. A check of this section would help you in reviewing the theory of operation of single-phase motors.

Steps in analyzing motor troubles should proceed in a logical sequence to determine what repairs are required for reconditioning the motor: (1) Inspect the motor for defects, such as, cracked end bells, bent shaft, broken or burned wiring; (2) check the motor for bearing troubles; (3) test the motor for grounds, opens, and shorts (see armature and 3-phase stator sections). If rewinding is required, record the necessary data on a motor data card (fig. 7-47).

CENTRIFUGAL SWITCHES

Burnt starting windings and defective centrifugal switches are frequently the causes of inoperative single-phase motors. Figure 7-48 shows the two major parts of a centrifugal switch. The centrifugal switch is located inside the motor on the rear end bell. It is used to disconnect the starting winding after the rotor has reached a predetermined speed, usually 75 percent of the full load speed. The action of the



73.130
Figure 7-48.—Two major parts of a centrifugal switch.

centrifugal switch is as follows: The contacts on the stationary part of the switch (the stationary part is mounted on the end bell) are closed when the motor is not in motion and completes the circuit through the starting winding. When the motor is energized and reaches approximately 75 percent of full load speed, the rotating part of the switch (mounted on the rotor) is forced by centrifugal force against the stationary arm, thereby breaking the contact and disconnecting the starting winding from the circuit. The motor is then operating on the running winding as an induction motor (fig. 7-49).

When a motor is overloaded, the speed slows and allows the centrifugal switch to energize the starting windings, then the motor speeds up enough so that the centrifugal switch opens the starting circuit again. This constant opening and closing of the starting winding circuit will cause the failure of the winding.

The condition of the switch must be checked periodically to determine that the switch contacts are clean and that all moving parts function properly. Stalling while starting or failure to start may indicate a faulty centrifugal switch. If this happens, power to the motor must be secured immediately or the starting winding will soon overheat and burn out.

SPLIT-PHASE MOTORS

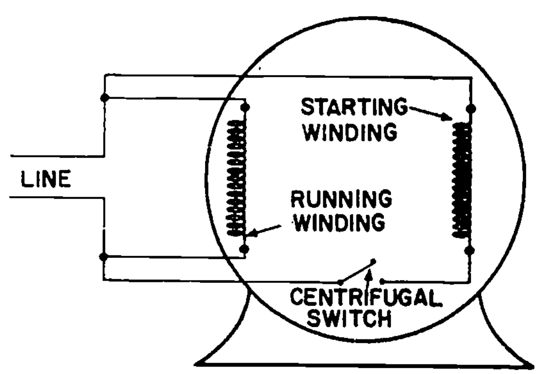
To analyze troubles in a split-phase motor, the first check after the obvious physical checks have been made, is for appropriate voltages at the terminal block. The next check is for grounds, shorts, or opens. Check to see if the rotor revolves freely. If the rotor turns freely when no voltage is applied, but locks when energized, you will know that the bearings are worn enough to allow the iron in the rotor to make contact with the iron in the pole pieces.

CAPACITOR MOTORS

The capacitor motor is similar to the split-phase motor except that it has a capacitor installed either on top of the motor, on the end of the frame, inside the housing, or even remote from the motor.

A capacitor-start motor does have a centrifugal switch for removal of the starting winding when the rotor has reached 75 percent of its rated speed. The capacitor-run motor does not have this switch. The starting winding stays in the circuit continuously.

The procedure for repair and troubleshooting capacitor motors is the same as it is for the split-phase motor except, of course, for the capacitors. Before applying the leads of a capacitor, disconnect the power and be sure to discharge the capacitor terminals. Upon completion of the tests, BE SURE TO DISCHARGE THE CAPACITOR TERMINALS. Replace the capacitor, if tests indicate a defective capacitor, with an identically rated capacitor.

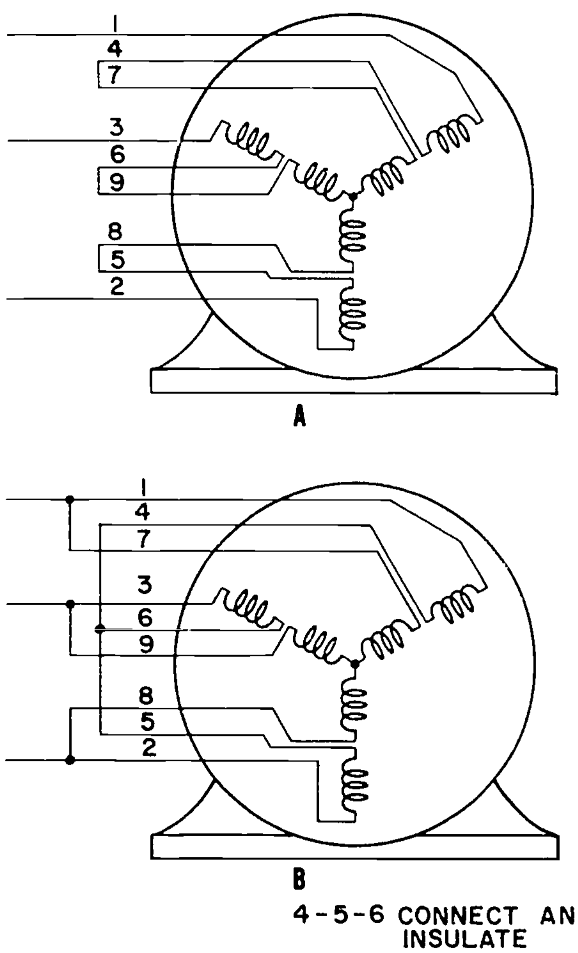


73.131
Figure 7-49.—Connections of a split-phase motor.

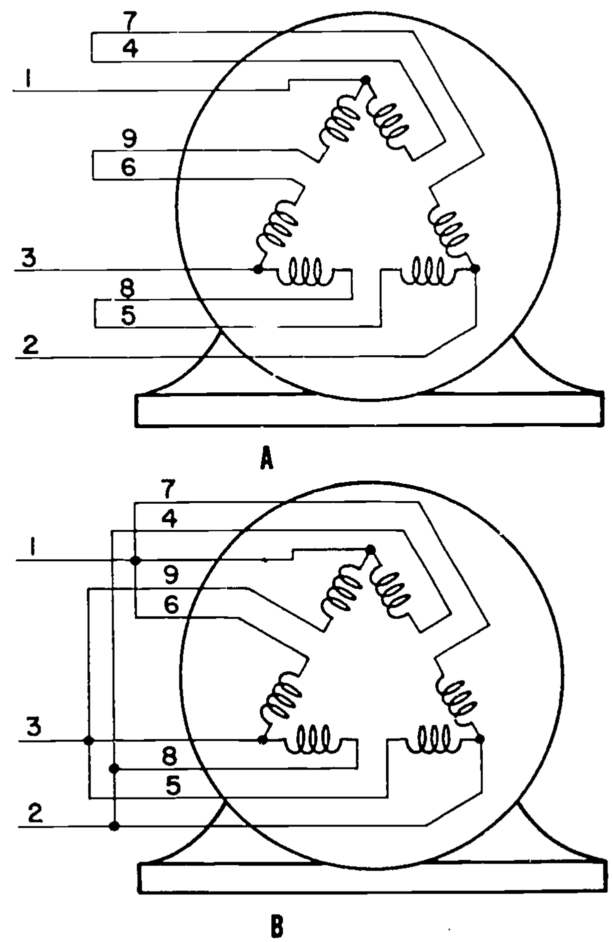
3-PHASE MOTORS

The windings in a 3-phase induction motor consist of coils, groups, and phases. For the 4-pole motor (the most common type), there are 36 slots and 36 coils. These coils are placed three coils to a group, three groups to a pole. Each of the three groups in a pole constitutes a phase. Phases are lettered A, B, and C.

Coils or groups of coils can be connected in various ways, such as series delta, parallel delta, series star and parallel star. Figure 7-50 shows a star-connected motor, with series connection for higher voltage in view A, and parallel connection for lower voltage in view



73.143
Figure 7-50.—Star-connected motor.(A) Series; (B) Parallel.



73.144
Figure 7-51.—Delta-connected motor. (A) Series; (B) Parallel.

B. Most 3-phase motors are connected for dual voltage with nine leads brought out to the terminal box on the motor, so that the coils can be connected in parallel for the low voltage or in series for the higher voltage. The choice between star or delta connection therefore depends on the voltage available from the power source.

Figure 7-51 shows a delta-connected motor, with series connection for higher voltage in view A and parallel connection for low voltage in view B.

Checking for trouble in a 3-phase motor follows the same procedure as that used for a single-phase motor, except that the 3-phase motor has more coils to check for grounds, shorts, and opens.

First isolate the trouble as to phases, then open the connections in the particular phase to separate the groups and check again. When the faulty group has been located, open the connections of the three coils in the group to locate the faulty coil. For an emergency connection, this coil can be cut out in the same manner as described for cutting out a coil in the armature.

With a 3-phase motor, one fuse can open and the motor will keep running (with less power and more current). When the motor stops, it cannot start again with the opened fuse in the line. When a fuse opens, replace all three fuses with fuses known to be good, and test the old fuses later on a fuse-testing circuit at the electric shop. To ensure that all possible trouble points have been covered, it is a good idea to follow a troubleshooting checkoff list.

GENERATORS

You should review the information regarding generators presented in Basic Electricity, NAVPERS 10086-B. Any time you are required to work on any generators, be sure to consult the appropriate technical manuals. These list a variety of difficulties you may encounter, some possible causes, and repair methods.

CLEANING MOTORS AND GENERATORS

The importance of keeping all insulation clean must be emphasized. Dust, dirt, and foreign matter (carbon, copper, mica, and so on) tend to block ventilation ducts and increase resistance to the dissipation of heat, causing local or general overheating. If the particles are conducting or form a conducting paste through the absorption of moisture or oil, the winding may be eventually short circuited or grounded. Abrasive particles may puncture insulation; iron dust is particularly harmful since the dust is agitated by magnetic pulsations.

The four acceptable methods of cleaning motors and generators are wiping, use of suction, use of compressed air, and use of a solvent.

Wiping with a clean, lint-free, dry rag (such as cheesecloth) is effective for removing loose dust or foreign particles from accessible parts of a machine. When wiping, do not neglect such parts as the end windings, mica cone extensions at the commutator of d-c machines, slip-ring insulation, connecting leads, and terminals.

The use of suction is preferred to the use of compressed air for removing abrasive dust and particles from inaccessible parts of a machine because it lessens the possibility of damage to insulation. If a vacuum cleaner is not available for this purpose, a flexible tube attached to the suction side of a portable blower will serve as a satisfactory substitute. Always exhaust the blower to a suitable sump or overboard when used for this purpose. Grit, iron dust, and copper particles should be removed only by suction methods whenever possible.

Compressed air must be clean and dry when used for cleaning electrical equipment. Air pressure up to 30 pounds per square inch may be used on motors or generators. A throttling valve should be used on air lines that carry higher pressure than is suitable for blowing out a machine. Before the airblast is turned on the machine, any accumulation of water in the air pipe or hose must be thoroughly blown out, and both ends of the machine must be opened to allow a path of escape for the air and dust. The use of compressed air will be of small benefit if the dust is not suitably removed from the machine. The most suitable method is to attach a suction blower to an opening in the opposite end from the air jet to remove the dirt-laden air.

The use of solvents for cleaning electrical equipment should be avoided whenever possible; however, their use is necessary for removing grease and pasty substances consisting of oil and carbon or dirt. Alcohol will injure most types of insulating varnishes and should not be used for cleaning electrical equipment. Solvents containing gasoline or benzine must not be used for cleaning purposes under any circumstances. Carbon tetrachloride is not to be used because of its extremely high toxicity.

Approved Solvents

Inhibited methyl chloroform (trichloroethane), FSN GM 6810-664-0388, is one of the principal approved solvents for cleaning electrical equipment but liberal ventilation must be provided by exhaust fans or portable blowers if this solvent is used for more than a few minutes.

In the rare cases when means of ventilation are impractical, an air line respirator or oxygen breathing apparatus (OBA) must be used if exposure to the solvent vapors is for more than a few minutes.

Inhibited methyl chloroform is very corrosive in its action on metal and may prove injurious to certain insulation. Before using any solvent, apply it to a small area or sample of the insulation to be cleaned. If it injures the insulation, do not use it. Clean freshwater, preferably warm or hot, may be used as an emergency substitute for inhibited methyl chloroform. Water should be used only as an emergency substitute and the equipment must be thoroughly dried after any application of water.

Do not spray inhibited methyl chloroform on windings. It will collect in pools and do more harm than good. The solvent should be applied by moistening a lint-free cloth with the fluid and lightly rubbing the surfaces to be cleaned; repeat the process if necessary to loosen the dirt. After wiping the insulation with solvent it should be thoroughly dried with a clean lint-free cloth.

Inhibited methyl chloroform is detrimental to good commutation and should be kept from coming in contact with the commutator or brushes of d-c machines.

Inhibited methyl chloroform should never be used on hot equipment as the accelerated evaporation will increase the toxic hazards.

Trichloroethylene (FSN G6810-184-4794) is another approved solvent widely used in a vapor process for degreasing metals. It should not be used for cleaning electrical insulation because of its strong solvent action on these materials. The toxic effects of trichloroethylene are similar to those of inhibited methyl chloroform.

Dry cleaning solvent, type II (FSN W6850-274-5421), is an approved safety type solvent. The fire and health hazards of this solvent have been minimized. The efficiency of this solvent is somewhat less than the previously discussed chlorinated solvents but the hazards to personnel are also reduced.

Precautions

During the use of any solvent the following precautions must be observed:

Guard carefully against fire.

Use vapor-proof or watertight portable lights if supplementary lighting is required.

Have fire extinguishers available for immediate use.

Prevent possible sparks caused by one metallic object striking another.

If a spray or atomizer (not normally used for routine cleaning) is used, ground the nozzle.

Avoid saturation of the operator's clothing with the solvent.

Provide liberal ventilation by means of exhaust fans or portable blowers.

When using inhibited methyl chloroform or trichloroethylene, protect against breathing the fumes (a chemical cartridge respirator such as a gas mask will not prevent suffocation since the vapors from these solvents displace air and oxygen). Cleaning should be done under the observation of someone familiar with artificial respiration.

Do not apply solvents on hot equipment or in the presence of open flames. The chlorinated solvents form highly toxic phosgene gas on contact with open flame.

No less than two persons should be assigned to cleaning operations in a single compartment.

General signs of fume poisoning by chlorinated hydrocarbons include headache, nausea, mental confusion, and in some instances a kind of drunken behavior similar to that caused by alcohol. When any of the above symptoms are observed, the person should immediately be removed from the toxic atmosphere to fresh air or a well-ventilated space.

Wear rubber gloves when constant contact of approved solvents is unavoidable. The solvents dry out the skin and cause it to crack and bleed.

GENERAL MAINTENANCE

The essential points in the maintenance of electric generators and motors are: keep insulation clean and dry and of high resistance, keep electrical connections tight, and keep machines in good mechanical condition.

Keep all small pieces of iron, bolts, and tools away from the machines. Where it is necessary to do any soldering, make sure that no drops of solder get into the windings and that there is no excess of solder on soldered joints which may later break off due to vibration and fall into the windings.

Do not disturb the commutator clamping bolts on d-c machines. Interference with these may make it necessary to turn or grind the commutator to restore it to service.

Other bolts and mechanical fastenings on both the stationary and rotating members should be tightened securely when the machine is installed, checked after the equipment has run for a short time, and thereafter checked at regular intervals to make sure that they are tight. Particular attention should be given to the bolts used to clamp any insulation.

If an inspection of a rotor shows that there is looseness of keys, bolts, or other fastenings, a check should be made for evidence of damage due to this looseness. Such looseness may result in worn dovetail keys, damaged windings, or broken dovetails on the end plates. Two or three drivings (with a punch and hammer) usually will ensure the tightness of the keys, but they should be checked regularly.

The banding wire on d-c armatures should be checked at regular intervals to make sure that it is tight.

The outboard bearing on some generators (both a-c and d-c) is electrically insulated from the frame; or the bearing pedestal is insulated from the base and the bearing oil piping to prevent the flow of shaft currents through the bearing. In the former case, insulation is accomplished by means of a shell of insulating material installed between the bearing shell and the bearing housing. In the latter case, the bearing insulation is accomplished by using insulating shims under the pedestal and insulated holding down bolts and dowels. Also insulated couplings are provided in the bearing inlet and outlet oil piping flanges (for force feed bearings). Special attention should be taken to ensure that this insulation is not damaged or that conducting paths around this insulation are not inadvertently provided. For instance, care should be taken when painting machines furnished with insulated pedestals not to paint over the insulating shims, washers, and oil piping couplings. Bearing currents, if of sufficient magnitude, will rapidly ruin a bearing. These currents are caused by electromotive force generated in the shaft and structural parts of a generator unless it is carefully designed and constructed to minimize their occurrence. An insulated bearing (or pedestal) breaks the circuit and protects the bearings from damage so long as the insulation is effective.

Inspect all electrical connections (particularly terminals and terminal board connections) at frequent intervals to make sure they are tight. Loose connections result in increased contact resistance and increased heating which may result in breakdown. Use locknuts, lockwashers, or other means to lock connections which tend to become loose because of vibration. Inspect soldered terminal lugs for looseness or loss of solder, and tighten solderless terminal lugs occasionally. When electrical connections are opened, clean all oil and dirt from contact surfaces before reconnecting. If the contact surfaces are uncoated copper, sandpaper and clean immediately before joining. If the contact surfaces are silverplated, do not use sandpaper. Use silver polish or a cloth moistened slightly with an approved solvent. Coat the finished joint with insulating varnish. Steel bolts for making electrical connections should be zinc- or cadmium-plated. Make sure that exposed electrical connections are adequately insulated to protect against water and moisture and injury to personnel. This applies especially to exposed connections at terminal straps extending outside the frames of propulsion motors and generators.

Lubrication

IMPROPER GREASING PROCEDURES ARE A FREQUENT CAUSE OF DAMAGE TO ROTATING ELECTRICAL MACHINERY PROVIDED WITH GREASE-LUBRICATED BALL BEARINGS. The trouble is generally caused by forcing an excessive quantity of grease into the bearing housing, with either one or both of the following results:

1. Grease is forced through the bearing housing seals and onto the windings and, in the case of d-c machines, onto the commutators where it causes deterioration of insulation, and eventually results in grounds or short circuits.

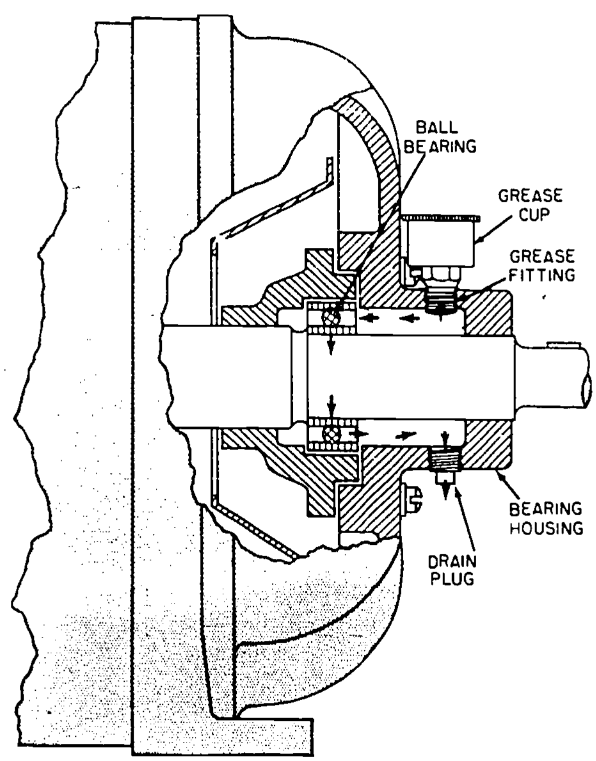
2. The excessive quantity and pressure of grease in the bearing housing result in churning, increased temperatures, rapid deterioration of the grease, and ultimate destruction of the bearing.

The following instructions apply to equipment except oil-lubricated bearings, synchros, and similar devices where friction must be maintained at an absolute minimum, and equipment for which approved lubrication charts or other specific instructions are furnished by the Navy. Except for the equipment to which they do not apply, the following instructions should be carefully observed in order to avoid failure of electrical equipment because of improper greasing practices:

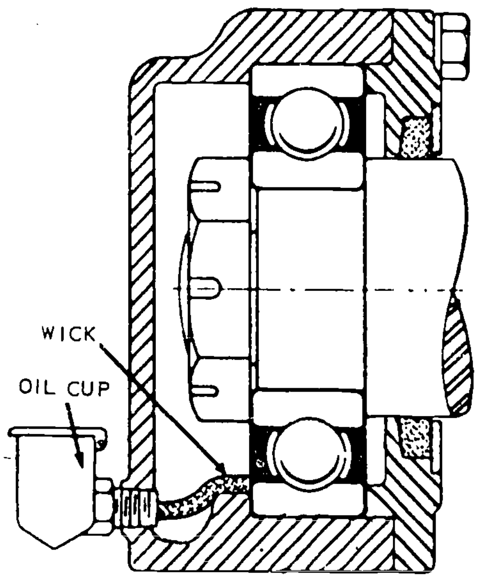
Motors and generators provided with bearings that should be lubricated with grease are now normally delivered from the manufacturer with the grease cups removed from the bearing housings and replaced with pipe plugs. The grease cups are delivered with the onboard repair parts or special tools. It is recommended that grease cups (fig. 7-52) be attached to electric motors and generators only when the bearings are being greased. When the grease cup is removed from the bearing housing after a bearing has been greased, the hole which remains should be plugged with a suitable pipe plug. When this procedure is used, the grease cups should remain in the custody of responsible maintenance personnel and can be stored in the workshop or toolroom. This procedure is particularly advantageous when the motors and generators maintained by a particular group of maintenance personnel need only relatively few different sizes of grease cups. This procedure should also be followed for motors and generators which have been supplied with grease cups attached to the machine. CARE SHOULD BE TAKEN TO MAKE SURE THAT A GREASE CUP IS CLEAN BEFORE IT IS USED TO ADD GREASE TO A BEARING AND THAT THE PIPE PLUG USED TO REPLACE THE GREASE CUP AFTER GREASING IS ALSO CLEAN.

Some electric motors and generators may be equipped with oil-lubricated ball bearings. Lubrication charts or special instructions are generally furnished for this type of bearing and should be carefully followed by personnel maintaining the equipment. In the absence of other instructions, the oil level inside the bearing housing should be maintained approximately level with the lowest point of the bearing inner ring. This will provide enough oil to lubricate the bearing for a considerable operating period, but not enough to cause churning or overheating.

One common method by which the oil level is maintained in ball bearings is the wick-fed method. In this method, the oil is fed from an oil cup to the inside of the bearing housing through an absorbent wick, which also filters the oil and prevents leakage through the cup in the event momentary pressure is built up within the housing. A representative wick-fed, oil-lubricated ball bearing is shown in figure 7-53.



77.68
Figure 7-52.—Grease-lubricated ball bearings.



77.69
Figure 7-53. — Wick-fed ball bearings.

The frequency with which grease must be added depends upon the service of the machine and the tightness of the housing seals, and should be determined for each machine by the engineer officer. Ordinarily, the addition of grease will not be necessary more often than once every 6 months. When a bearing housing is too full of lubricant, the churning of the grease generates heat which in turn causes deterioration of the grease. Under these conditions the grease separates into oil and minute abrasive particles, becomes increasingly stickly, and tends to seal the bearing against fresh lubricant until the resulting friction, heat, and water cause failure of the bearing.

Greasing Procedures

Bearings which normally operate at a temperature of 194° F (90° C) or below should be lubricated with grease in accordance with Military Specification MIL-G-18709, Stock Nos. W9150-235-5544 and W9150-235-5564.

To avoid the difficulties caused by an excessive amount of grease, add it only when necessary. Grease is added according to the following instructions:

1. Run the machine to warm up the bearings.

2. Wipe the outside of the grease fitting and drain the plug free of all dirt.

3. Remove the bearing drain plug, and make sure the passage is open by probing with a clean screwdriver or similar implement.

4. Remove the pipe plug on top of the grease pipe (open the grease pipe by probing as above). Select the proper grease cup, empty and clean out the grease cup (top and bottom). Install the bottom portion of the grease cup on the grease pipe.

5. Fill the bottom portion of the grease cup with clean grease, fill the top portion (cap) of the grease cup only half full of grease.

6. Thread the half filled cap of the grease cup onto the fully filled bottom of the grease cup and screw it down as far as it will go (by hand). Keep the machine running continuously while adding grease.

7. Repeat steps (5) and (6) above until clean grease begins to emerge from the drain hole.

8. Continue to run the machine and let grease run out of drain hole until drainage stops (normally about 30 minutes). Remove the grease cup and replace the pipe plug.

9. Replace the drain plug.

10. If a grease gun must be used, remove the drain plug in the bearing housing while greasing and use extreme care to avoid inserting too much grease or applying more than just enough pressure to get the grease into the housing.

High Temperature Grease

Bearings which normally operate at a temperature above 194° F (90° C) should be lubricated with a silicone grease in accordance with Military Specification MIL-L-15719A, Stock No. W9150-257-5358. Machines which require this special grease have a caution plate stating "USE HIGH TEMPERATURE GREASE" which is attached near the grease fitting by the manufacturer.

SLEEVE BEARINGS

A SLEEVE bearing is a type of sliding bearing employed in electric motors and generators. These bearings are used in large equipment, such as turbine-driven ship's service generators and propulsion generators and motors. The bearings may be made of bronze, babbitt, or steel-backed babbitt.

Preventive maintenance of sleeve bearings requires periodic inspections of bearing wear and lubrication.

Wear

Large motors and generators are usually provided with a gage for measuring bearing wear. Bearing wear on sleeve bearing machines not provided with a bearing gage can be obtained by measuring the air gap. It is usually not necessary to measure air gaps on machines which have ball bearings because the construction of the machine is such as to assure bearing alignment. Bearing wear of sufficient magnitude to be readily detectable by air gap measurements would be more than enough to cause unsatisfactory operation of ball bearings and would be detected in this way.

Air gaps on a sleeve bearing machine not provided with a bearing gage should be measured at each end of the machine. Air gaps can be measured with an air gap feeler. This is a machinist's feeler gage with a blade long enough to reach into the air gap without removing the end brackets of the machine. Before making the measurements, clean the varnish from a spot on a pole or tooth of the rotor. A spot should also be cleaned at the same relative position on each field pole of a d-c machine. For a-c machines, at least three and preferably four or more spots spaced at equal intervals around the circumference should be cleaned on the stator. The air gap measurements should be taken between the cleaned spot on the rotor and the cleaned spot on the stator, turning the rotor to bring the cleaned spots on the rotor opposite each of the cleaned spots on the stator.

If one end of the machine is accessible only with difficulty, either of the following procedures may be used:

1. Take several measurements at one end in accordance with the procedure described above, and two measurements approximately 90° apart at the less accessible end. If these two do not differ greatly from the mean of the measurements at the other end, the air gap is reasonably uniform at both ends.

2. Take several measurements at one end of the machine in accordance with the procedure described above, and average these to obtain the average air gap, or obtain the average air gap from records of preceding measurements. The average air gap is one-half the difference between the inside diameter of the stator (or field pole arrangement) and the outside diameter of the rotor (or armature), and is not affected by bearing wear. Procure a long, narrow strip of steel. The thickness of the steel strip should be 20 percent less than the average air gap for average air gaps smaller than 0.040 inch; it should be 10 percent less for average air gaps larger than 0.040 inch. Test the air gap by trying to push this strip all the way from one end of the air gap to the other. This test should be made at four points 90° apart, if possible, and if not, at a number of points (not less than three) spaced at approximately equal intervals around the circumference. The test can be repeated with a slightly thicker strip if a closer estimate is needed.

It is more important to have uniformity of air gaps at all points than to have the gap conform exactly to the specified limits. If the air gap at any of the places tested differs from the average air gap by more than 20 percent for average air gaps smaller than 0.040 inch, or by more than 10 percent for average air gaps larger than 0.040 inch, the bearings should be realigned, repaired, or replaced. Usually an inequality of air gaps which is not greater than specified above will not cause unsatisfactory operation. If, however, trouble is experienced, such as vibration or excessive noise which cannot be traced to any other cause than unequal air gaps, it is advisable to realign, repair, or replace bearings to equalize air gaps, even if the measured inequalities are within the limits given.

Lubrication

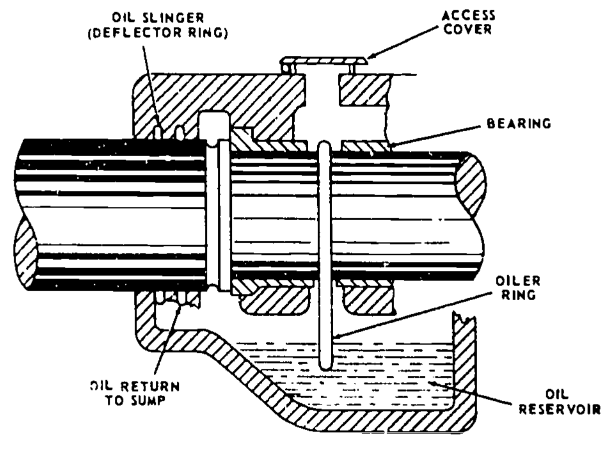
Every precaution should be taken to keep the oil and bearings clean and free from water or foreign particles.

Do not add oil while the machine is running. This affords an opportunity for oil mist or spray to escape from the bearing housing and be blown on the machine windings.

Bearings having an overflow gage should be filled until the oil is about one-sixteenth inch from the top of the gage. If the machine is equipped with an oil filter gage, the gage should be filled to the manufacturer's oil level mark, or (if no mark is available) the gage should be between two-thirds and three-quarters full at all times. Be sure that the gage glass and piping to the gage are clean or the glass will give false indications of the oil level. If the bearing has neither an overflow gage nor an oil filter gage, fill to a level so that the oil ring dips into oil to a depth of about half the shaft diameter.

When the bearing and bearing housing are in good condition, there should be no loss of oil. If the proper oil level cannot be maintained without adding oil, it is probable that oil is leaking from the bearing. Be sure the oil sight gage connection to the bearing is tight. Much of the oil that leaks out of a bearing is drawn into the machine by the cooling air and sprayed onto the windings where it causes oil soaked dirt to collect. This condition tends to cause insulation failure. If oil leakage is suspected, carefully clean and chalk the shaft outside the bearing, the outside of the bearing housing, and the parts of the rotor adjacent to the bearing. If the machine is throwing oil, discoloration of the chalk will so indicate after a short run. This test will not be dependable unless the chalked part is perfectly clean at the beginning of the test. If leakage is found, the labyrinth seal in the bearing housing should be corrected to make it effective. Another possible source of leakage is from the vent with which some labyrinths are provided. Made sure that any such vent is not stopped up and that it terminates in still air of atmospheric pressure where there is no current of air over the vent that will suck oil out of the bearing housing or oil vapor out of the vent into the machine. Such oil leakage is often due to overfilling the bearing or trying to fill the bearing through the vent.

Bearing oil should be renewed semiannually. Drain the oil off by removing the drain plug, then flush the bearing with clean oil until the drained oil flows clean.



77.239

Figure 7-54.—Diagram of an oil-ring lubricated bearing.

Oil Rings and Bearing Surfaces

An opening is provided in the top of the bearing for checking the condition of the oil rings and bearing surfaces (fig. 7-54). Periodic inspections are necessary to make certain that the oil ring is rotating freely when the machine is running. With the machine stopped, the bearing surfaces should be inspected for any signs of pitting or scoring.

Trouble Analysis

The earliest indication of sleeve bearing malfunction normally appears as an increase in the operating temperature of the bearing. This increase is due to the heat generated in the extremely sensitive oil film separating the rotating journal from the bearing surface and is governed by the slipping or shearing of the oil molecules. When the bearing is operating satisfactorily, the film temperature remains stable; but when the equilibrium of the oil film is interrupted, rapid and sharp changes occur in the temperature of the oil film. Oil is supplied under pressure from a central system to sleeve bearings in some large generators.

Thermometers are usually inserted in the discharge line from the bearing as a means of visually indicating the temperature of the oil as it leaves the bearing. Thermometer readings are taken hourly on running machinery by operating personnel. However, a large number of bearing casualties have occurred in which no temperature rise was detected in thermometer readings, and, in some cases, discharge oil temperature has actually decreased. Therefore, after checking the temperature at the thermometer, a followup check should be made by feeling the bearing housing whenever possible. Operating personnel must thoroughly familiarize themselves with the normal operating temperature of each bearing so that they will be able to recognize any sudden or sharp changes in bearing-oil temperature. Many large generators are provided with bearing temperature alarm contactors which are incorporated in the alarm system. The contactor is preset to provide an alarm when the bearing temperature exceeds a value detrimental to bearing life. If bearing malfunction is indicated, the affected machinery should be secured as soon as possible. A motor with overheated sleeve bearings should be unloaded, if possible, without stopping the motor. If stopped immediately, the bearing may seize. The best way to limit bearing damage is to keep the motor running at light load and supply plenty of cool, clean oil until the bearing cools down.

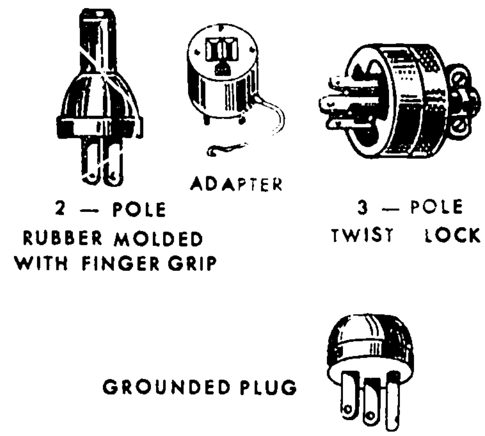
The temperature of sleeve bearings and the outer races of ball bearings should not be allowed to exceed the following values:

1. Sliding contact (sleeve) bearings — 82° C (180° F).

2. Rolling contact (ball) bearings on class A or B insulated motors — 90° C (194° F).

3. Rolling contact (ball) bearings on class H insulated motors — 150° C (300° F).

The permissible operating temperature is too high to be estimated by sense of touch. Temperature measurements are needed to determine whether a bearing is overheated. A thermometer securely fastened to the bearing cover or housing will usually give satisfactory measurements. A thermometer should not be inserted into a bearing housing; it may break and necessitate disassembly to remove glass and mercury.

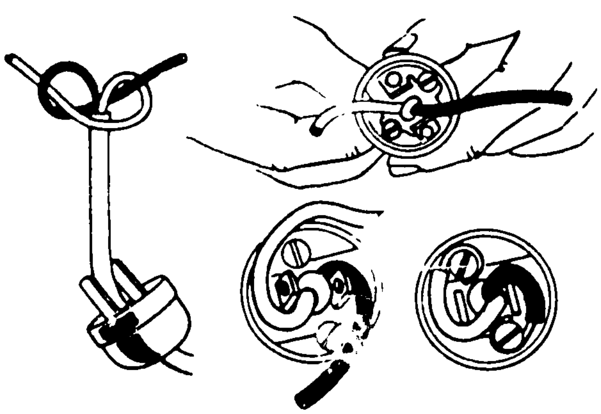


5.13A

Figure 7-55. — Attachment plugs.

Any unusual noise in operating machinery may also indicate bearing malfunction. Whenever a strange noise is heard in the vicinity of operating machinery, a thorough inspection must be made to determine its cause. Excessive vibration will occur in operating machinery with faulty bearings, and inspections should be made at frequent intervals in order to detect its presence as soon as possible.

Portable appliances and devices that are to be connected to receptacles have their electrical cords equipped with plugs (fig. 7-55) that have prongs which mate with the slots in the outlet receptacles. Equipment connected by a cord or plug should be grounded in accordance with the National Electric Code, article 250-45. A three-prong plug can fit into a two-prong receptacle by using an adapter. If the electrical conductors connected to the outlet have a ground system, the lug on the lead wire of the adapter is connected to the center screw holding the receptacle cover to the box. Many of these plugs are permanently molded to the attached cords. There are other types of cord-grips that hold the cord firmly to the plug. Twist-lock plugs have patented prongs that catch and are firmly held to a mating receptacle when the plugs are inserted into the receptacle slots and twisted. Where the plugs do not have cord-grips, the cords should be tied with an Underwriter's knot (fig. 7-56) at plug entry to eliminate tension on the terminal connections when the cord is connected and disconnected from the outlet receptacle.



5.13B
7-56. —The Underwriter's knot.

DOMESTIC OIL BURNERS, WINDOW AIR-CONDITIONERS, AND LARGE APPLIANCES

When you are assigned to "B" company or a Public Works electric shop, you will be involved with troubleshooting and repair of various types of heating units, window air-conditioners, and appliances. Your knowledge of wiring diagrams and schematics, along with a good understanding of locating grounds, shorts and opens in a circuit, will be of prime importance.

OIL BURNERS

The electrical portion of an oil burner in almost any type of automatic oil heating installation contains motors, relays, and thermostats. The sequence of operation will vary with the type and application of each oil burner. The manufacturer's manual will furnish you with this needed information. Examples of two types of operations follow.

Forced Hot-Water System

A thermostat senses the need for heat in the room and turns on the relay, closing the low-voltage circuit across the terminals of the relay (fig. 7-57). The relay, when turned on by the thermostat, starts the circulator and also energizes the stack switch. This closes the line-voltage circuit to the circulator and the low-voltage circuit across the terminals of the stack switch. The stack switch, when energized by either the relay or the operating immersion controls, starts the oil burner if the stack has cooled, returning the helix-operated contacts to the starting position. The oil burner runs until the thermostat is satisfied. The thermostat then turns off the relay which stops the circulator and simultaneously breaks the low-voltage circuit across the terminals of the stack switch, stopping the oil burner operation. When the operating immersion control used to maintain summer-winter (domestic hot water) senses the drop in the boiler water temperature, it energizes the stack switch as required. It breaks the low-voltage circuit across the relay terminals when the water temperature reaches its cutout setting. This operation does not affect the unit's hot-water circulator.

Forced Warm-Air System

A thermostat senses the need for heat in the room and energizes the stack switch which closes the low-voltage circuit across the terminals of the switch (fig. 7-58). When the stack switch is energized by the thermostat, it starts the oil burner, if the stack has cooled, returning the helix-operated contacts to the starting position. The oil burner runs until the thermostat is satisfied and turns off the stack switch, which opens the low-voltage circuits across the terminals to the stack switch or until the bonnet temperature reaches its present high point. This causes the safety limit control, which is part of the fan-and-limit control, to turn off the unit.

As soon as the combustion unit increases the bonnet temperature enough to ensure that warm air will be forced out of the residence registers, the fan side contacts of the fan-and-limit control starts the blower. The blower continues to function until the bonnet temperature is reduced to its cutoff setting.

There are basically three components in an oil burner ignition system:

1. The step-up high-voltage transformer which steps up from 115 volts line on the primary

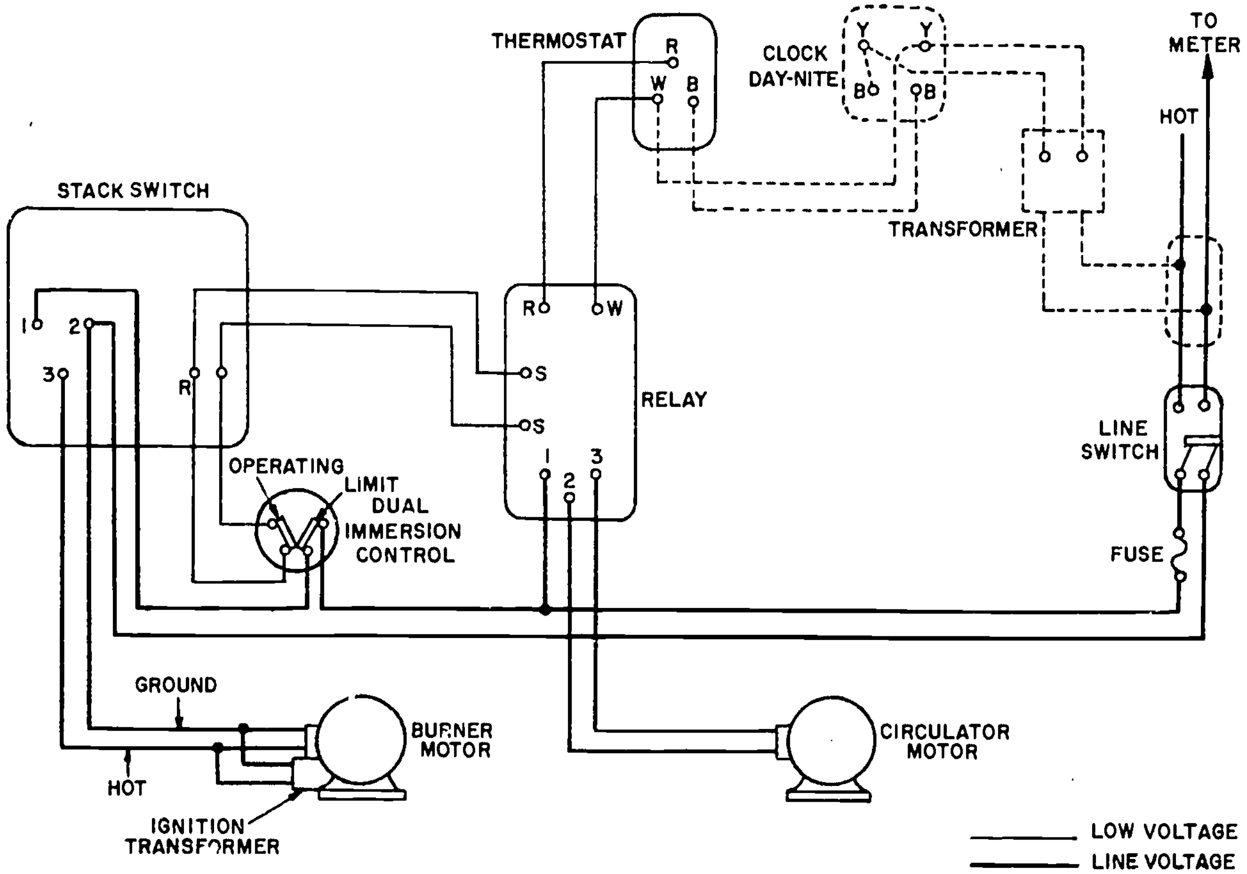


Figure 7-57.—Oil burner circuit, forced hot-water system.

side of approximately 10,000 volts on the secondary side.

2. Ignition wires or bus bars which are a point of contact for the high-voltage source to reach the electrode assembly.

3. The electrode assembly which consists of a combination of insulated porcelain and steel electrodes for spark which is used for ignition.

This system provides the spark or lightoff required to ignite the fuel oil as it enters the combustion chamber. The spark must be correctly positioned to provide immediate ignition to the prepared fuel. It cannot be delayed, weak, or off-target. These and other defective conditions can result in odor, dirt, inconvenience, and possible hazard. Some units are designed so that the spark remains on for just a short period after providing initial ignition or lightoff. In other types of systems, the spark remains on during the entire firing cycle.

This spark occurs on the tips of the two properly positioned electrodes, and the high-voltage transformer provides the electricity to produce it. It must be strong enough to bridge the correctly set gap between the electrodes. Setting the electrode gaps will vary with each unit. Manufacturer's instructions will be provided for each burner.

AUTOMATIC WASHERS

The main electrical parts of an automatic washer are: timer, water temperature switch or mixing valve, limit switch, door safety switch, water level control, and main drive motor. The timer is the most involved of all these parts. Figure 7-59 shows a wiring diagram of the electrical parts controlled by the timing device.

The time cycle in figure 7-60 is for a typical top load washer. The sequence of operation for the regular cycle is as follows: The fill cycle turns on the mixing valves. The machine fills with water until the timer advances to wash. The wash cycle starts the two-speed motor on low and works the agitator until the cycle is complete. There is a pause between the wash and spin rinse cycle. The spin rinse turns the motor on high speed and a clutch device engages the water pump to spin out the wash water. Fresh water is also sprayed into the machine during this cycle. The machine stops at the end of the spin cycle and fills again. The entire process is then repeated except for rinsing instead of washing. There will be variations depending on the manufacturer. The final spin uses no water, so the clothes will come out damp dry.

ELECTRIC DRYERS

The main electrical parts of a dryer are: electric heating elements, thermostats to control heat, a motor to turn the main drum assembly, and a timer to select cycle operations. Most dryers have a cutoff switch on the door which stops the dryer when the door is opened. Many dryers have a 40-watt ozone bulb to help condition the air. This bulb requires either a ballast coil or a ballast bulb. Both high-limit and low-limit operating thermostats are used in dryers to control the air temperatures that pass through the clothes. These are located in

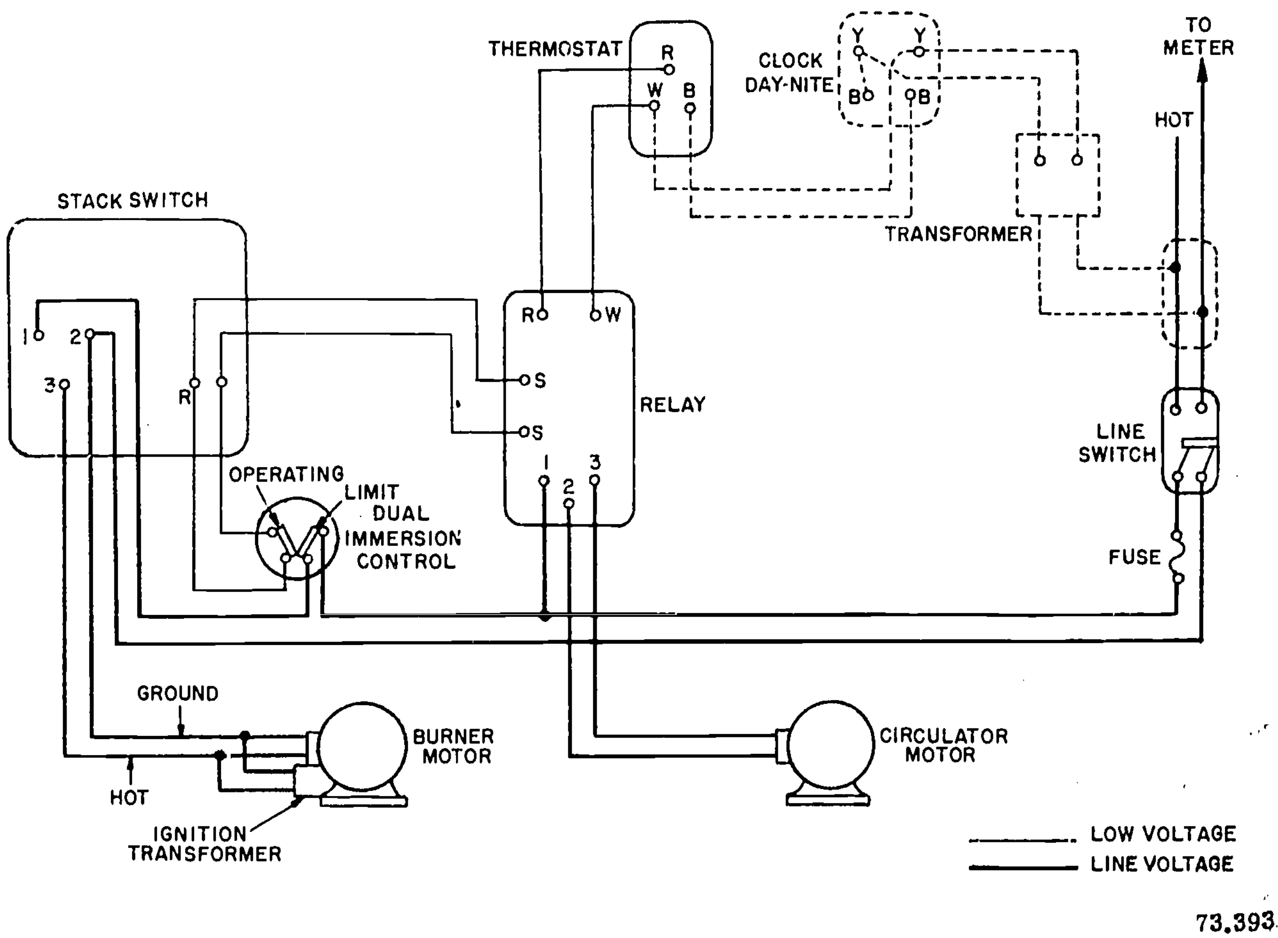


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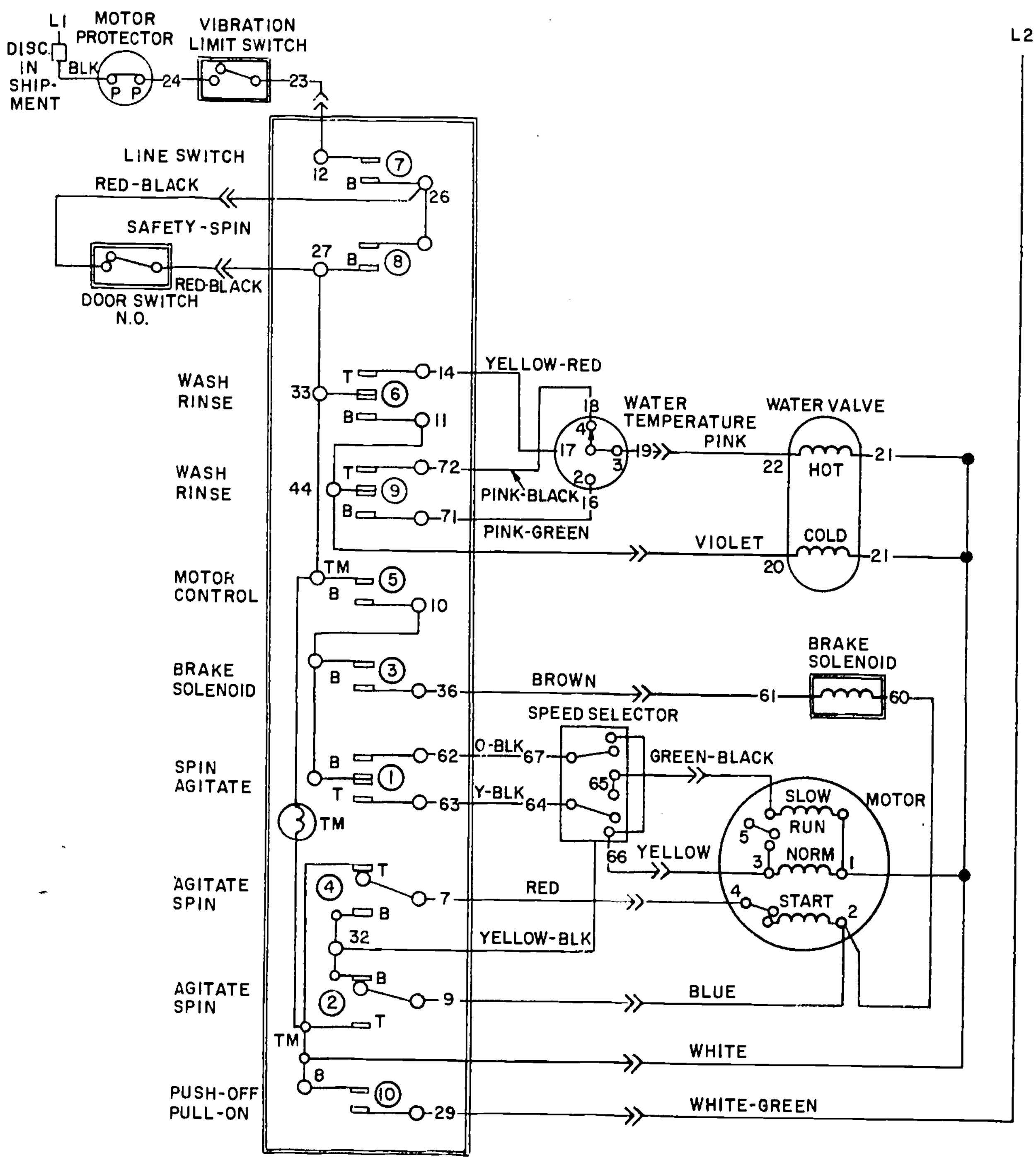
Figure 7-58.—Oil burner circuit, forced warm air system.



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73.394
Figure 7-59. — Wiring diagram showing electrical connections from timer to other electrical parts.

REGULAR CYCLE	TIME(MIN.)	GENTLE CYCLE	TIME(MIN.)
FILL	4	FILL	4
WASH	2-10	WASH	3
PAUSE	1	PAUSE	1
SPIN	2	SPIN	2
SPIN SPRAY	1	SPIN SPRAY	1
FILL	3	FILL	3
OVERFLOW RINSE	4	OVERFLOW RINSE	1
DEEPWAVE RINSE	1	DEEPWAVE RINSE	1
PAUSE	1	PAUSE	1
SPIN	1	SPIN	3
SPIN SPRAY	1		
SPIN	5		
TOTAL	34 MIN.	TOTAL	20 MIN.

73.395
Figure 7-60.—Time cycle for an automatic washer.

the exhaust housing and can be easily checked during operation by a voltage check. The tester will indicate a voltage each time the contact is opened. Safety thermostats should show continuity between terminals at normal room temperature. Holding a small flame close under it should cause it to open, indicating an open circuit across its contacts. Dryer timers are fairly simple to troubleshoot. Some timer drive motors and switching mechanisms can be replaced, but in most cases it is more practical to replace the timer. Figure 7-61 is a wiring diagram for an electric dryer.

ELECTRIC HOT-WATER HEATERS

An electric hot-water heater is a metal water-storage tank with one or two electric heating elements, thermostatically controlled to heat water in the tank. It is a simple device and among electrical problems that may arise are: no power, defective thermostat, thermostat out of calibration, or defective heater element.

The hookup of a hot-water heater will vary with the size and application of each unit. Where power consumption is a problem, a hot-water heater may be placed on a timeclock and taken out of the system during maximum power consumption periods (fig. 7-62). Most units at advanced bases will be hooked up without a timing device as shown in figure 7-63. The thermostats in the figure operate as follows: The single-throw thermostat is in series with the heating element and has only one set of contacts, which open and close in response to the temperature at the bottom of the water-heater tank. The double-throw thermostat controls both the upper and lower heating elements. The switch closes the circuit in the upper heating unit whenever the water temperature in the top of the tank becomes lower than the thermostatic switch setting. When the top part of the tank reaches a preset temperature, the switch opens the contacts to the upper unit and, by a toggle action, closes the contacts to the lower unit. The lower unit comes on and remains on until its preset thermostat is satisfied.

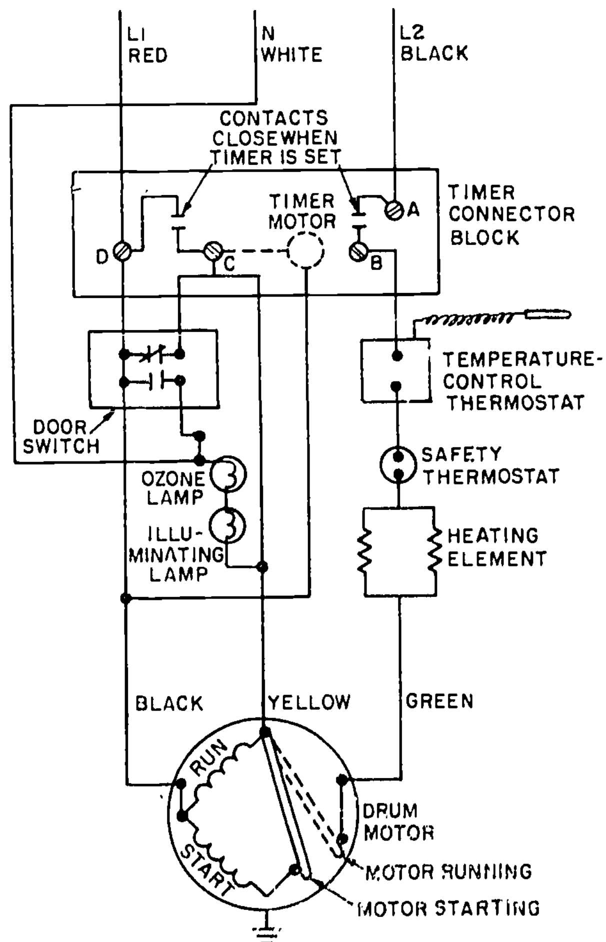

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Figure 7-61.—Schematic of an automatic dryer.

RANGES

The electric ranges you will be working on wil vary in size and style but will all basically work the same. Surface heating elements work off a selector switch which changes the voltage and resistance value of the element, giving you a variety of heating temperatures. Figure 7-64 shows how this is accomplished. Oven elements work off a thermostat to control heat temperature and a timing device for automatic shutoff as shown in figure 7-65.

In troubleshooting, start by checking to ensure proper voltage to the unit, then checking out each element and control device. The heating element, though ruggedly constructed, might become open-circuited. This can be checked out with an ohmmeter. Normal resistance is somewhat less than 100 ohms. If elements are opened, replacement is necessary. If the heating element checks normal, but the unit doesn't heat up, the controls should then be checked. Voltage measurement is the most reliable test for a switch. When turned off, the measurement across the switch terminals should read full line voltage, 120 or 240 volts. When the switch is on, the reading should be zero across the terminals. Any voltage reading across the terminal of a closed switch indicates a fault. Replacing a faulty switch involves the disconnection and reattachment of many wires. A sketch or identifying tags should be used to ensure the correct relocation of

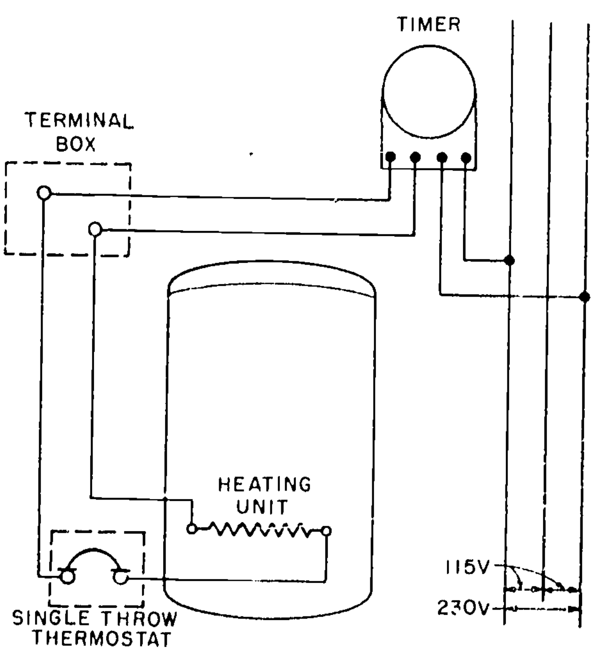

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Figure 7-62.—Wiring diagram for a limited-demand, time-controlled, hot-water heater.

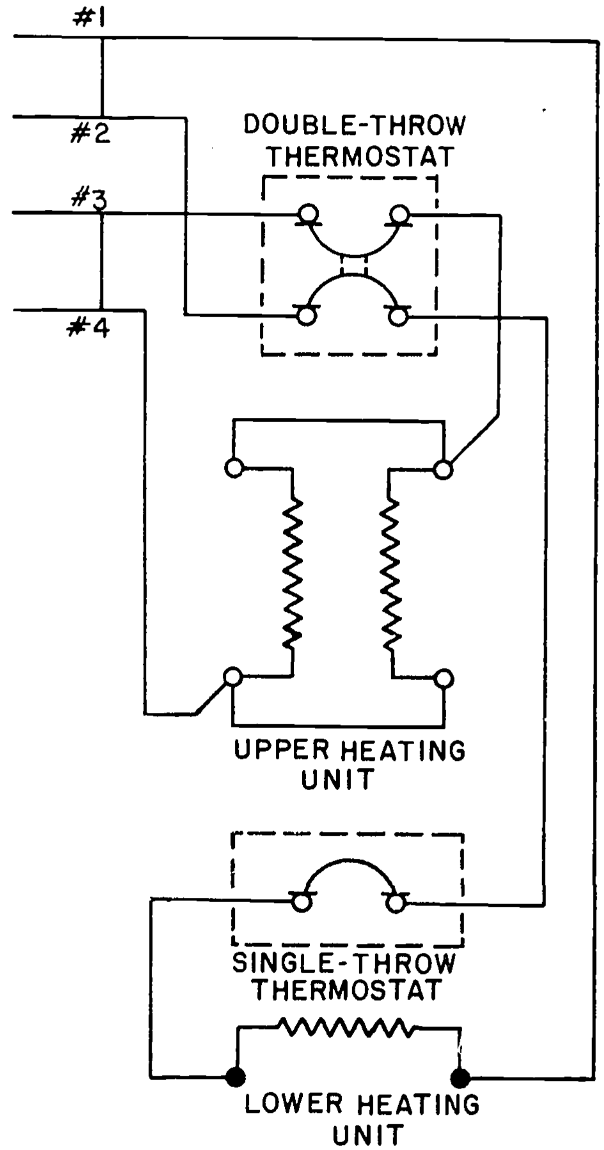

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Figure 7-63.—Wiring connections for an electric water heater having two heating units.

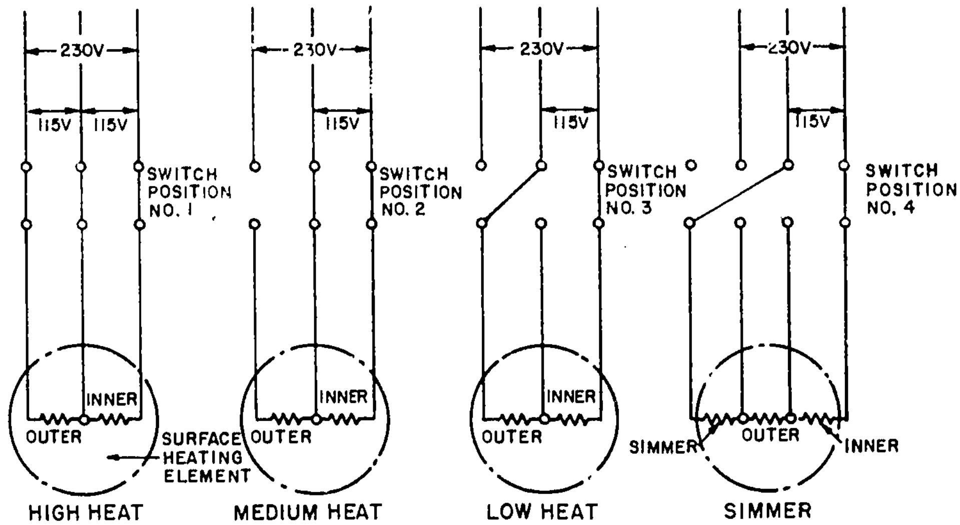

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Figure 7-64.—Surface heating element with four-heat switching.

wires. Oven thermostats control temperature and are factory calibrated for that unit. Some units can be recalibrated but most must be replaced. When replacement is necessary the exact type is preferred; however, universal type replacements are available. The manufacturer's instructions that come with a thermostat will give you the exact method for installing and calibrating the device.

Faulty wiring is the final check. Unless arcing damage is evident, test a wire by disconnecting both ends from the circuit; then check it with an ohmmeter. A good wire checks 0 ohms; a faulty one, infinity (∞). Replacement of a faulty conductor should be made with asbestos-covered heater wire. Solder is not used because it will melt; spade-tongue or quick-connect terminals are used instead.

HERMETIC COMPRESSOR APPLICATION

Hermetic compressors contain the motor and compressor in a sealed unit. The motor and compressor work off the same shaft; therefore, no shaft seal or belt drive is required. This arrangement provides a more compact assembly and takes up less space.

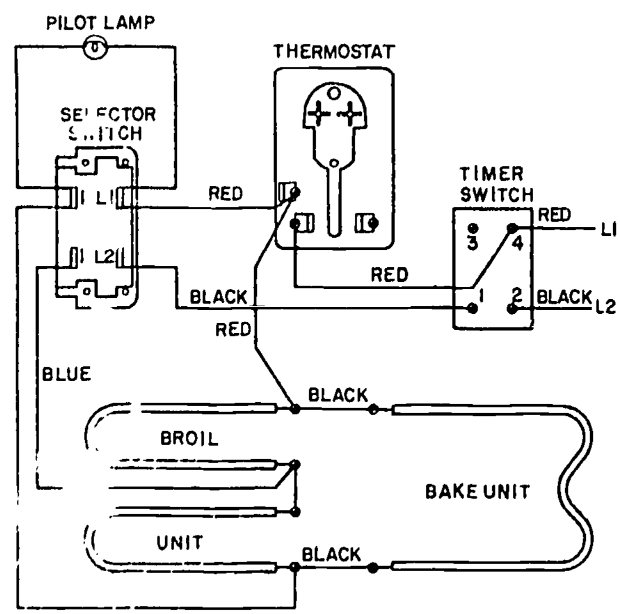

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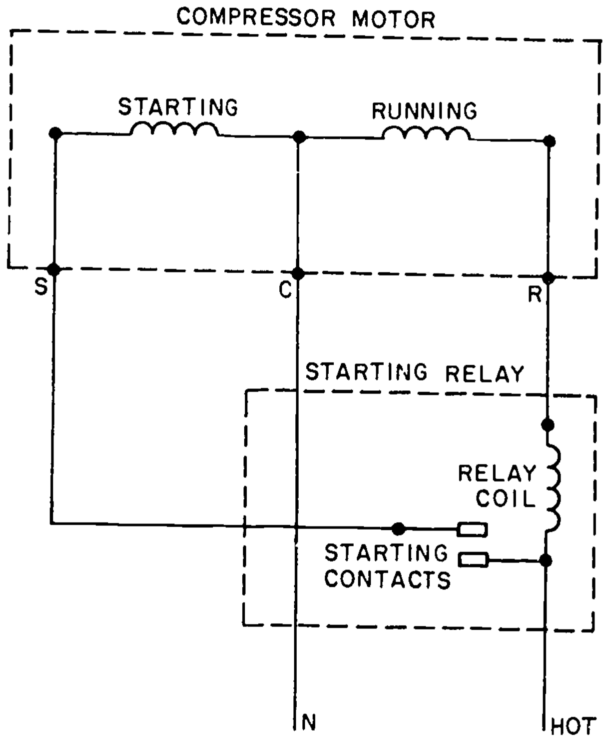
Figure 7-65. —Oven heating circuit with two heating units.



73.401
Figure 7-66.—Schematic wiring of a compressor-motor and starting relay.

Almost all household refrigerators, window air-conditioners, and ice cube machines you will be working on have hermetic compressors.

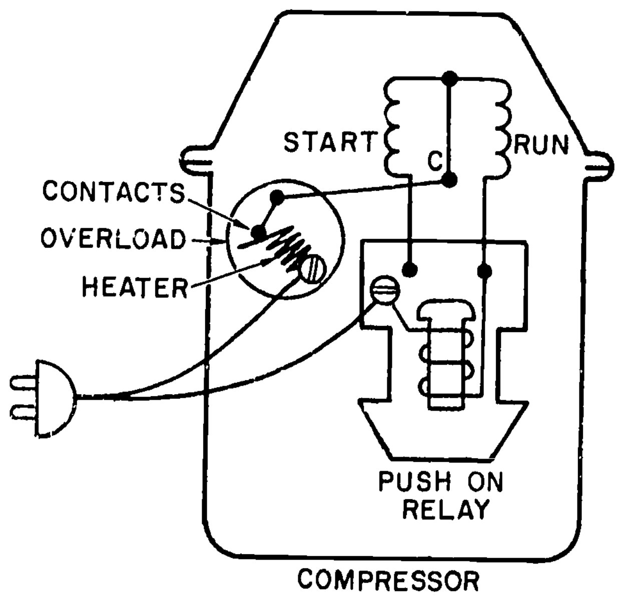
Compressor motor sizes will vary, depending on application and capacity of the system. The compressor motor consists of a starting and running winding. The running winding is energized during the complete cycle period, whereas the starting winding is energized only during the starting period, because additional starting torque is required in single-phase units.

STARTING RELAYS are used at the moment of starting. (figure 7-66). When the electrical circuit is completed by a control device calling for the system to operate, current passes through the starting relay coil and running winding. The high current drawn by the running winding causes the starting relay coil to close its contacts. The current passing through the starting coil induces an out-of-phase, magnetic field in the stator and starts the motor. As the motor speed increases, the current in the running winding is reduced. This drops the value of the current in the starting relay and opens its contacts, taking the starting winding out of the circuit. The motor continues to run on the running winding as an induction motor.

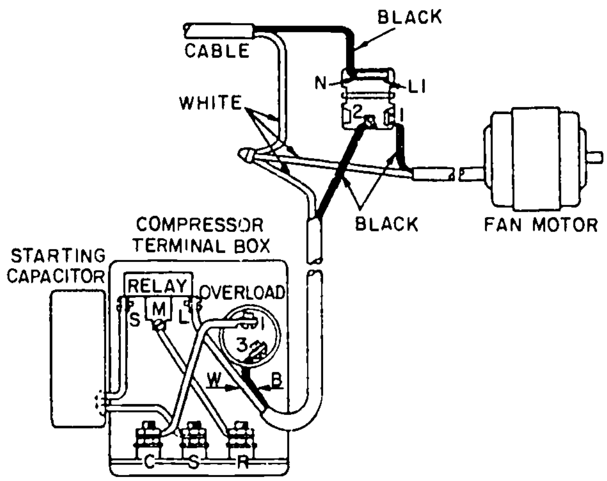
OVERLOAD PROTECTION is provided by a bimetallic strip in series with the compressor windings (fig. 7-67). Should the current in the motor windings increase to a dangerous value, the heat developed by the current passing through the bimetallic overload will cause its contacts to open circuit. This will stop the motor before any danger occurs. When the bimetallic strip cools, it will return the contact to the closed position.

WINDOW AIR-CONDITIONERS

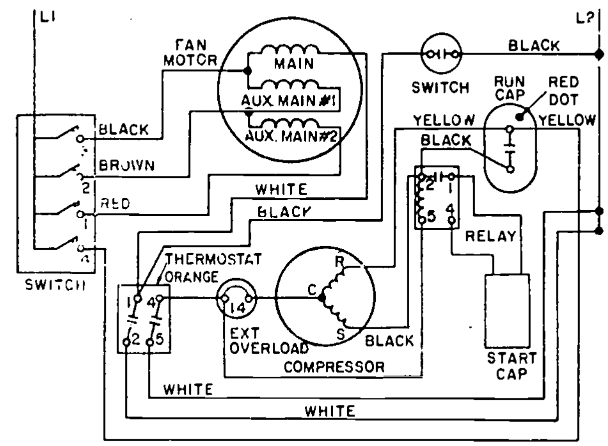
A basic electrical system for a window air-conditioner consists of a hermetic compressor



73.402
Figure 7-67.—Wiring diagram of a compressor-motor with overload protection.

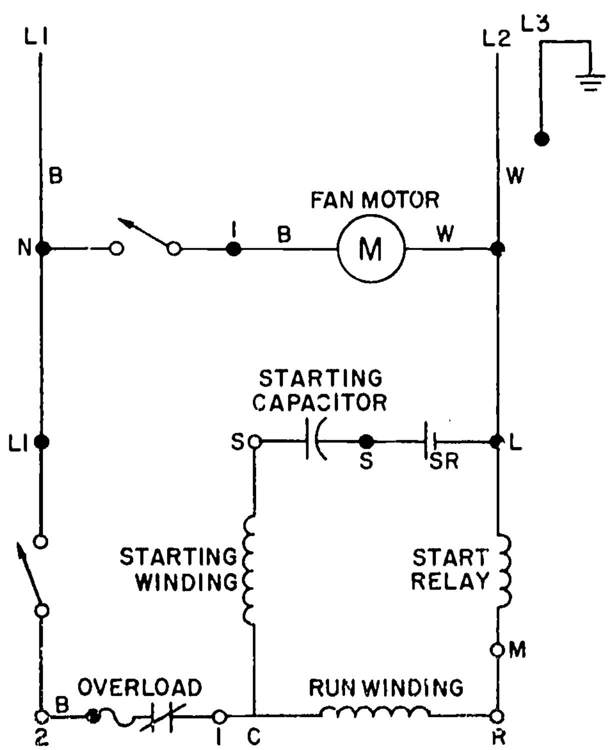


73.403
Figure 7-68.—Air-conditioner diagram with one fan motor and hermetic compressor.



SWITCH POSITION	CONTACTS CLOSED
OFF	NONE
FAN	LI TO 2
HI-COOL	LI TO 3 & 4
MED-COOL	LI TO 2 & 4
LO-COOL	LI TO 1 & 4

73.405
Figure 7-70.—Window air-conditioner with starting and running capacitors.



73.404
Figure 7-69.—Schematic wiring diagram of the air-conditioner in figure 7-68.

with thermal overload protection, starting relay, starting capacitors, running capacitor (on some models), motor thermostat, and unit control switch (on-off and fan speed). Hermetic compressors, thermal overloads, and starting relays have been previously discussed.

The choice of starting or running capacitors of air-conditioners depends on the type and size of unit. The thermostat or temperature control stops and starts the compressor in response to room temperature. Its principle of operation will be discussed later in this chapter.

In studying figures 7-68 and 7-69, you will notice a starting capacitor is used. These capacitors are of the electrolytic type and are used in motor starting windings to effect an increase in starting torque. Starting capacitors are intended for short and infrequent compressor

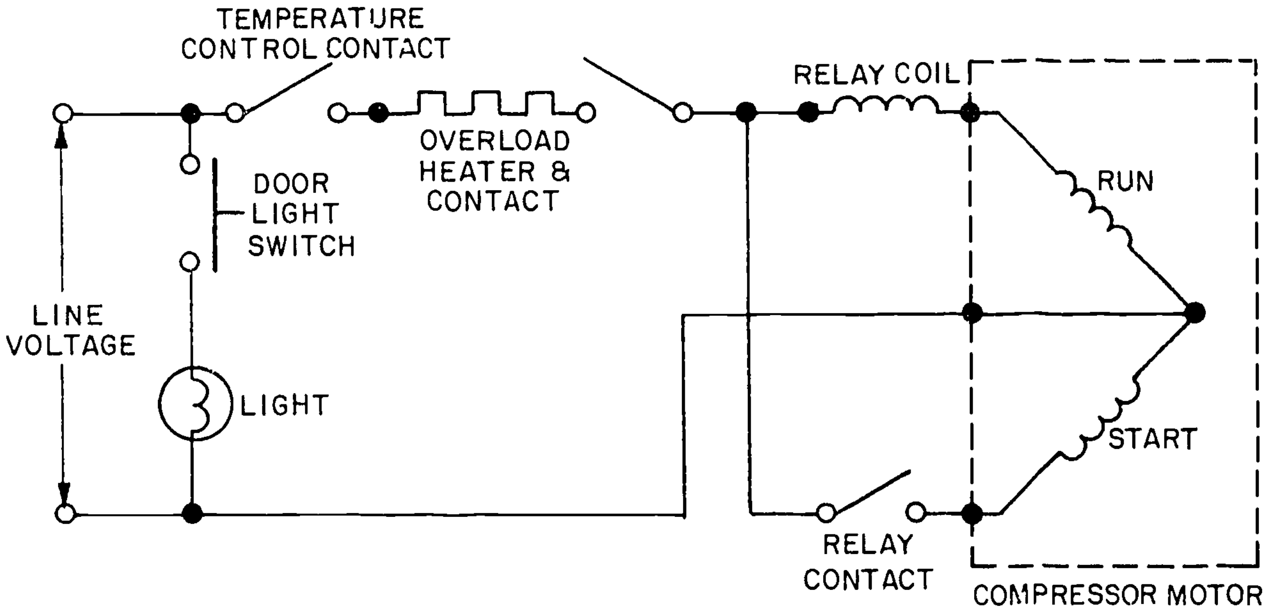
TROUBLE	POSSIBLE CAUSE	POSSIBLE REMEDY
UNIT WILL NOT RUN	BLOWN FUSE	CHECK FOR AN ELECTRICAL SHORT AT WALL RECEPTACLE. REPLACE FUSE.
	BROKEN OR LOOSE WIRING	
	LOW VOLTAGE	CHECK VOLTAGE. VOLTAGE SHOULD BE WITHIN 10% OF THAT SHOWN ON THE UNIT NAMEPLATE.
	DEFECTIVE UNIT STARTING SWITCH	CHECK VOLTAGE AT SWITCH. IF THERE IS PROPER VOLTAGE AT SWITCH, BUT NO CONTINUITY THROUGH IT, REPLACE SWITCH.
FAN RUNS, BUT COMPRESSOR WILL NOT OPERATE	INOPERATIVE THERMOSTAT	IF TURNING THERMOSTAT TO ITS COLDEST SETTING DOES NOT START COMPRESSOR (AND ROOM TEMPERATURE IS ABOVE 75°), BUT SHORTING ACROSS ITS TERMINALS DOES, CHANGE THERMOSTAT.
	LOOSE OR BROKEN WIRING	CHECK UNIT WIRING AND WIRING CONNECTIONS AT THE UNIT STARTING SWITCH AND AT THE COMPRESSOR.
	STARTING CAPACITOR FAULTY (IF USED)	CHECK STARTING CAPACITOR (IF USED).
	RUNNING CAPACITOR FAULTY	CHECK RUNNING CAPACITOR.
	RELAY FAULTY (IF USED)	CHECK RELAY (IF USED).
	OFF ON OVERLOAD OR OVERLOAD FAULT	CHECK FOR OVERHEATED COMPRESSOR OR FOR DEFECTIVE OVERLOAD.
	LOW VOLTAGE	CHECK VOLTAGE.
UNIT BLOWS FUSES	SHORTED OR INCORRECT UNIT WIRING	CHECK UNIT WIRING.
	SHORTED STARTING OR RUNNING CAPACITOR	CHECK CAPACITORS.
	SHORTED OR STUCK COMPRESSOR	CHECK COMPRESSOR.
	COMPRESSOR STARTING DIFFICULTY	CHECK FOR LOW VOLTAGE. CHECK STARTING CAPACITOR AND RELAY.
	INCORRECT FUSE	CHECK FUSE SIZE.

73.406

Figure 7-71.—Troubleshooting chart for window air-conditioner.

starts. Any operating fault that would cause a starting capacitor to remain in the circuit for more than several seconds could cause its failure. Internally shorted capacitors will cause starting trouble and blown fuses; with open-circuited starting capacitors, the compressor may not run. Running capacitors are used in some systems. They are heavy-duty, oil-filled capacitors that can remain in the circuit continuously. Running capacitors also increase starting torque and reduce the running amperage by increasing the power factor.

Fan motors are usually of two types: split-phase capacitor motor or shaded-pole motor. The number of fan motor leads will vary, depending on the type of motor used. Shaded-pole motors will have either two or three leads, depending on whether the speed winding is incorporated in the motor, or if a reactor is used to reduce the fan speed. Figure 7-70 shows a circuit with starting and running capacitors. The fan motor speed is controlled by the motor windings. The unit control switch may be a rotating control dial or pushbutton type, depending on the



73.407

Figure 7-72.—Basic refrigerator wiring diagram.

manufacturer. Switching positions such as those shown in figure 7-70 are given in the manufacturer's instructions. Knowing the switch position makes troubleshooting the system easier.

Troubleshooting charts can be found in most manufacturer's manuals. These charts are intended to provide quick reference to the cause and correction of a specific fault (fig. 7-71).

HOUSEHOLD REFRIGERATORS

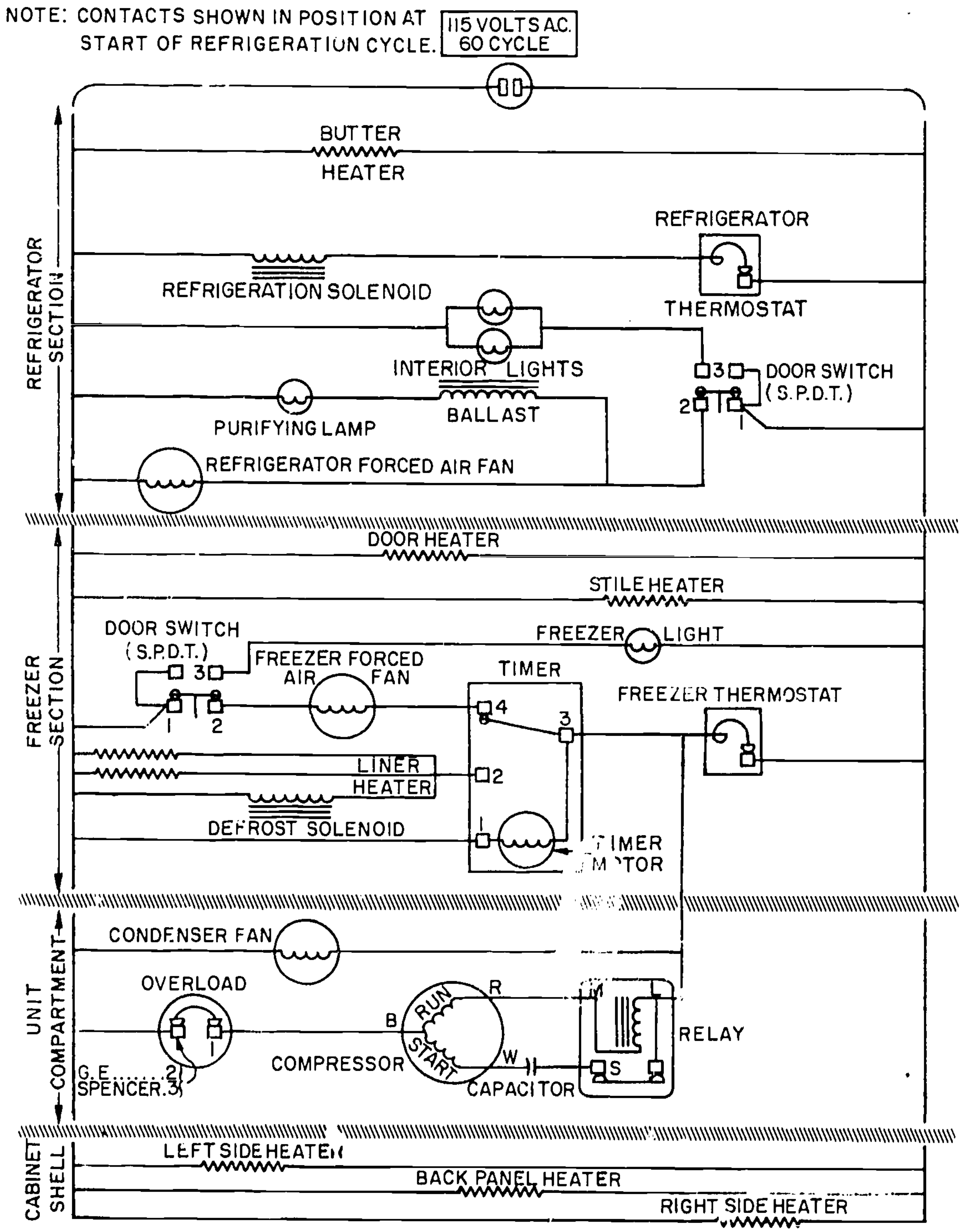
The electrical wiring of household refrigerators may differ considerably from unit to unit, depending on compressor protection, method of defrosting, and extra design features. The simplest form consists of a motor-compressor, light switch, and temperature control (fig. 7-72).

The temperature control or thermostatic switch operates on the expansion and contraction of a gas-filled bulb. As the temperature in the box rises, the gas expands, closing the contacts on a toggle switch. The hermetic compression comes on and the refrigeration cycle begins. When the box temperature drops to a preselected temperature, the thermostat opens, stopping the compressor.

Other refrigerators have automatic defrosting, internal forced-air fans, and panel heating elements. The automatic defrosting can be accomplished by several different methods, depending on the manufacturer. One method is shown in figure 7-73. The electric timer clock is preset to defrost the system every 12 hours. During this period the freezer fan motor is stopped and the heaters placed around the cooling coils are energized. This cycle lasts about 10 to 18 minutes, depending on the size of the unit. Most refrigerators have the wiring diagram on the back of the unit. You should study it before troubleshooting the electrical system.

Learning the sequence of operation of both the mechanical and electrical components (such as the defrost timing device) will save you time and needless disassembly of internal components, such as heaters placed around cooling coils. Take a few minutes to study each job; it will save time in the long run. Troubleshooting guides in the manufacturer's manual are a big help. The more you work on a system, the easier it will become to recognize possible causes of trouble.

243



73.408

Figure 7-73.—Diagram of refrigerator-freezer with automatic defrost.

CHAPTER 8

INTERIOR WIRING

At any Navy base, the electrical system consists of three parts: the power plant that supplies the electrical power, the distribution system that carries the electrical current from the generating station to the various buildings, and the interior wiring systems that feed the electrical power to the appliances and equipment within a building.

As defined here, interior wiring begins at the point where the distribution systems service leads are connected to the wiring from within the building and extends through each circuit of the building's interior wiring to the last fixture installation.

The interior wiring system must meet two essential requirements: it must be safe for personnel and the appliances it serves, and, further, must be capable of serving these appliances properly for as long as necessary.

In this chapter, we will discuss your responsibilities in meeting various code and specification requirements and a variety of techniques for installing, repairing and maintaining interior wiring.

SPECIFICATIONS AND REQUIREMENTS

All Navy electrical installations ashore must conform to rigid standards and specifications. As a CE, you must be aware of the requirements set by three sources: the Federal Government, which puts out military standards and specifications (MIL-STD's and MIL-SPEC's); the Naval Facilities Engineering Command (NAVFAC), which writes NAVFAC specifications; and the National Fire Protection Association, which prepares and publishes the National Electrical Code.

MILITARY STANDARDS AND SPECIFICATIONS

Although various industry and government agencies have developed many specifications and standards, the military has established its own MILITARY STANDARDS (MIL-STD's) and MILITARY SPECIFICATIONS (MIL-SPEC's). In many cases, these requirements are more rigid than their civilian counterparts, so that components can withstand the test of severe environmental and usage conditions.

NAVFAC SPECIFICATIONS

CE's are also required to follow the specifications issued by the Naval Facilities Engineering Command (NAVFAC) when performing any work involving electrical apparatus, distributing systems, and wiring. NAVFAC specifications, however, are all-inclusive and advise you of those specifications (MIL-STD, federal, or commercial) you must use for particular applications.

Remember that specifications, whether military or civilian, are updated periodically and you must check to see that you use the most current ones.

NATIONAL ELECTRICAL CODE

The NATIONAL ELECTRICAL CODE (NEC) is prepared and published every 3 years by the National Fire Protection Association. Its purpose is to safeguard personnel and buildings and their contents from hazards arising from the use of electricity.

How does this code minimize the dangers mentioned above? Briefly, the NEC provides:

- various methods of wiring and descriptions of materials,
- techniques for wiring design and protection,
- requirements of general and special equipment,

- special conditions and occupancy information, and

- a variety of tables and examples for calculations.

This wealth of information provides Construction Electricians with a strictly-to-be-observed guide that experience has shown will minimize electrical hazards to personnel and buildings. Study the NEC closely and learn it well. It will prove useful to you throughout your career as a Construction Electrician. As you advance in rate, you may be required to teach courses on its contents.

INTERIOR WIRING MATERIALS

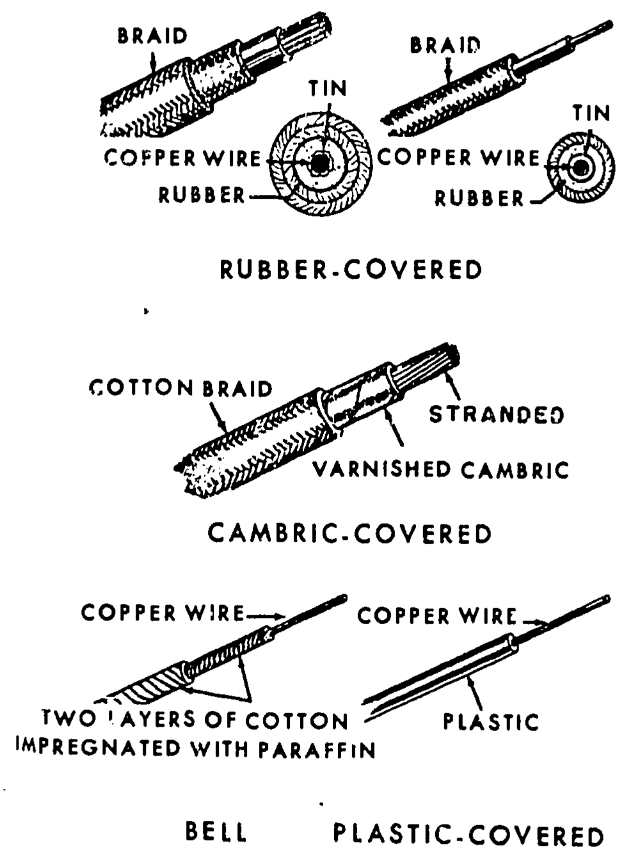
Every wiring job calls for its own particular type of material. Whether to use rigid, flexible, or thin-wall conduit might be a decision you will have to make. Use the information provided here to become familiar with installation requirements. Learn to use the proper cable, conductors, and conduit in the correct place. Make sure you are familiar with methods of bending, joining, and installing the various materials; and learn to select the proper fittings and accessories that you will need in installing materials. As you are referred to the NEC throughout this discussion, look up the articles indicated and get acquainted with the NEC book. It will be your guide on acceptable and safe procedures. A good Construction Electrician takes pride in doing a neat, safe and proper job.

CONDUCTORS

Electrical conductors generally consist of drawn copper or aluminum formed into a wire. They provide paths for the flow of electric current and usually have insulating material (fig. 8-1) encasing the metal. The insulation material is provided to minimize short circuits and to protect personnel. Atmospheric conditions, voltage requirements, and environmental and operating temperatures are factors considered in the selection of the type of insulating material for a particular job.

Single Conductors

A conductor may consist of a single solid wire or combination of a number of solid wires (stranded) which are not insulated from each other and share in carrying the total current.



73.301

Figure 8-1.—Single conductors.

Stranded conductor has the advantage of being more flexible than solid conductor, making it more adaptable for pulling through bends in conduit.

Conductors vary in diameter. Wire manufacturers have established a numerical system called the American Wire Gage (AWG) standard. Table 8 of the NEC and page 127 of Basic Electricity, NAVPERS 10086-B, show how this numerical system eliminates the necessity for cumbersome circular mil or fractional inch diameters when describing wire sizes. Notice that the wire gage numbers increase from 1 through 18 as the diameter of the wire decreases.

Size, Number, and Ampacity

The wire size most frequently used for interior wiring is No. 12 AWG, used as a solid copper conductor. Table 310-17, column 2, of the NEC shows the allowable ampacity of a single conductor in free air, No. 12 AWG (for types RUW, T, and TW insulation) to be 25 amperes. However, the minute that conductor is not alone in free air, and is placed in a raceway, cable or direct burial, you can see, by referring to Table 310-16, that its ampacity is reduced to 20 amperes, provided that not more than three conductors are in the raceway or cable. What happens if more than three conductors are in the raceway conduit, or cable? The following information indicates the reduced ampacities for a variety of numbers of conductors in such a situation.

Number of conductors	Percent [illegible]rmal cur[illegible]ing
4 to 6	[illegible]
7 to 24	[illegible]
25 to 42	60
43 and over	50

Suppose, now, that you have four to six No. 12 wires in a conduit. The allowable current-carrying capacity would be only 80 percent of normal, or 16 amps. To ensure a current-carrying capacity of 20 amps, you would have to use No. 10 wire, which has a normal current-capacity of 30 amps, 80 percent of which is 24 amps.

The type of wire used to conduct current from outlet boxes to sockets in the lighting fixtures is called fixture wire. It is usually size 16 or 18 AWG, stranded for flexibility.

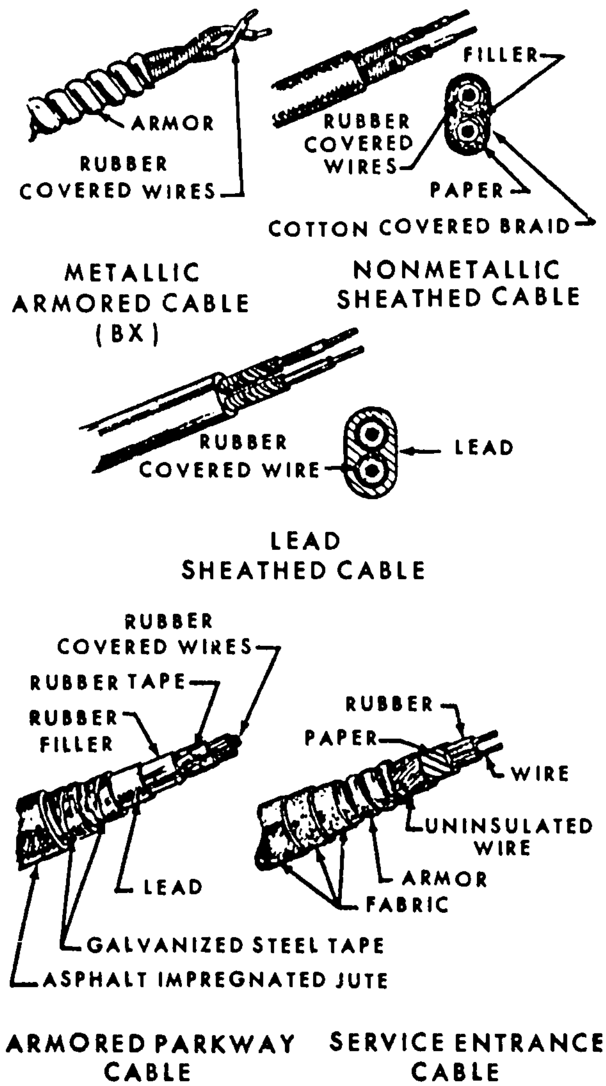
CABLES

A cable is an assembly of two or more conductors insulated from each other with an additional insulating or protective shield formed or wound around the group of conductors (fig. 8-2). A cable that contains two No. 12 wires is known as 12-2; if it contains three No. 12 wires, it is called 12-3. If a cable has two insulated No. 14 wires, as well as an uninsulated grounding wire, it is referred to as 14-2 with ground. This cable would contain one black and one white insulated wire. If it contains three insulated wires, the third wire is red.

Nonmetallic Sheathed Cable

Nonmetallic sheathed cable is usually called Romex, its trade name. It is the cable shown in the upper right-hand corner of figure 8-2. At one time, this cable consisted of two or three conductors, insulated with rubber or thermoplastic, with paper or jute insulation wound over the rubber or thermoplastic, and an overall braid covering the combined conductors. This type of cable is still found in many places either with or without a bare (uninsulated ground wire. Now, Romex cable is required to have a ground wire. A ground wire is used to ensure the grounding of all metal boxes in the circuit, and also furnishes the ground for grounded type convenience outlets.

Romex is available in sizes 14 to 2 AWG with 2 or 3 conductors. Sizes 14, 12, and 10



73.302
Figure 8-2. — Multiconductor cables.

are solid wires. Sizes 8 to 2 AWG are stranded conductors to a cable. Romex must be secured at intervals of not more than 4 1/2 ft and within 12 in. of each outlet box of fittings, except where finished in walls.

In naval installations Romex is used primarily for temporary work, such as on quonset huts. Civilian contractors, however, use it extensively for residential wiring. The NEC does not permit its use as service entrance cable, in commercial garages, in theaters built for more than 200 spectators, in storage battery rooms, in any hazardous location, or embedded in concrete. All connections in Romex must be made at junction or outlet boxes, and squeeze type connectors must be used for securing the cable to boxes.

In most installations where Romex is permitted, a ground wire must be used with the cable to furnish a continuous ground throughout the circuit. This ground wire is fastened under a screw in each outlet box to which the cable is connected. Another way to secure the ground wire is to wrap it backward over the braid in a close wrap and under the Romex clamp. This makes a very good bond. When using grounding type duplex receptacles, the ground wire can be fastened under the green grounding screw.

When making bends in Romex, the radius of the bend should be not less than five times the diameter of the cable.

BX Cable

BX, an armored metallic cable, is also used on naval installations for temporary wiring but, unlike Romex, its use in civilian installations is restricted. Most city building codes restrict the use of BX to oil burner control circuits and the like. A difficulty with BX is the fact that it tends to ground after installation. Small metal burrs on the armor can, because of vibration, penetrate the insulation and cause a ground. The trouble and expense involved in clearing a ground behind the wall covering, after a building is finished, can be easily imagined.

BX, like Romex, must be run continuous from box to box, with no splicing allowed between boxes. It must be secured at intervals not greater than 4 1/2 ft and within 12 in. from each outlet box or fitting, except where fished in walls. It must be secured to boxes with a squeeze-type connector. It is cut with a fine-tooth hacksaw, and a fiber bushing is installed over the conductors at each cut.

BX comes in sizes from 14 to 2 AWG and in cables containing 1, 2, 3, or 4 conductors. The armor on the cable furnishes a continuous ground between boxes.

Flexible Cord

A flexible cord is made up of two or more conductors, each insulated from the other, and usually fine-stranded. Flexible cord is used for such purposes as the connection of portable lamps, tools, and appliances; for elevator cables; and for the connection of stationary equipment in which connections must be frequently interchanged. It must not be used as a substitute for fixed wiring; or run through holes in walls, ceilings, or floors; or run through doorways, windows, or similar openings. It may not be attached to building surfaces or concealed behind building walls, ceilings, or floors.

Finally, flexible cord may be used only in continuous lengths — meaning that splices or taps in it are forbidden.

Insulation

Electrical conductors are available with various kinds of insulation such as rubber, thermoplastic, varnished cambric and asbestos. Paper, glass, silk and enamel are also used to insulate conductors, but with must less frequency than those previously mentioned.

The NEC recommends insulations of various kinds for use in dry, damp, and wet locations. A dry location is one which may become only temporarily subject to dampness or wetness. A damp location requires moisture-resistant insulation because it is subject to a moderate degree of moisture. Underground installations, those in concrete slabs and masonry, those in direct contact with the earth, and those subject to saturation with water or other liquids are considered wet locations. Just as humidity affects the choice of insulation for cables, temperature is also a factor to be considered. Different insulations have different maximum temperature ratings. Check the NEC to be sure you are using the appropriate insulation for the location and temperatures in which the conductors will operate. Some examples of the composition of insulation, the locations in which they are used, and their maximum temperatures follow.

Type RH is a heat-resistant compound which will stand higher temperatures than type R. The maximum temperature for RH is 167° F. It is used in dry locations.

Type RHW is a moisture-resistant rubber compound for use where the wire may be subject to wet conditions. The maximum temperature rating is 167° F. RHW is used in both wet and dry locations.

Type RUH is a very high grade rubber compound, consisting of 90 percent grainless rubber known as latex rubber. This type is often used for direct burial in dry locations. Maximum temperature rating is 140° F.

Common grades of thermoplastic insulation are type T, type TW, and type TA. Type T is suitable only for dry locations with maximum temperature of 140° F. Type TW is moisture-resistant. Again maximum temperature rating is 140° F. Type TA is a thermoplastic-asbestos compound which combines the characteristics of type T and type TW, and has a maximum temperature rating of 194° F. Its use is restricted to switchboard wiring.

Thermoplastic insulation has the advantages of long life, toughness, and a dielectric strength (that is, a capacity for insulating) equal to that of rubber. It requires no protective covering over the insulation.

Varnished cambric insulation is, in most respects, midway between rubber and paper in insulating quality. It is more flexible than paper but not as flexible as rubber. Its dielectric strength is greater than that of rubber, but not as great as that of impregnated paper. Varnished cambric insulation is not adversely affected by ordinary oils and greases. It is made in two types: the standard with a black finish, and the heat-resisting with a yellow finish. It is used on motor leads, transformer leads, and high-voltage cables. Its use is restricted to dry locations.

Asbestos insulation has, as the name implies, the highest capacity for resisting heat. Consequently, it is used for temperatures beyond the maximum limits set for other types of insulation. However, it is not satisfactory for damp or wet locations, and is limited to a maximum of 300 volts.

RIGID CONDUIT

Rigid steel conduit may be either black-enamel finished, sherardized (zinc-coated by heat), or galvanized. Black enamel and sherardized are not used much in the Navy, because these types deteriorate in damp locations or when exposed to the elements. The galvanized type can be installed outside, inside, or embedded in concrete, even in wet locations.

When conduit is installed in concrete, it must be embedded in the concrete, not in a cinder bed below it. In some overseas locations, the conduit must be given a good coat of red lead or asphalt paint as a preservative against corrosion caused by beach sand in the concrete and/or chemicals in the soil.

Rigid conduit comes in 10-ft lengths, threaded on both ends, each length having a coupling on one end for joining lengths together. Sizes range from 1/2 in. to 6 in. in diameter.

Cutting and Threading

The use of rigid conduit involves a good deal of cutting and threading of lengths. It is best to cut with a hacksaw or special conduit cutter. An ordinary revolving wheel pipe cutter leaves a heavy inside ridge that is difficult to remove and tends to jam the passing through of conductors. Always ensure that you make a cut at right angles to the axis of the pipe.

After the pipe is cut to the proper length, use a reamer to remove all burrs from the inside of the sawed end. The conduit should be held in a vise during cutting and reaming. If a regular reamer is not available, a large rattail or half-round file can be used to remove burrs. However, no matter what burring tool you use, you must get a smooth inside finish to allow for passage of the conductors.

The next step is thread-cutting on the cutoff end. For the smaller pipe you use a ratchet-type die that turns directly with the handle. On larger pipe you use a die with a mechanical advantage—that is, one on which the die makes only a part of a revolution when the handle makes a complete revolution.

A conduit-threading die, like a plumber's die, makes a tapered thread, so that a coupling starts rather loosely but binds hard as it is set up. This tight connection serves two purposes: (1) it makes a watertight joint, and (2) it makes a good electrical connection for a continuous ground throughout the length of the conduit. To ensure a tight connection when it is impossible to screw a piece of pipe into a coupling, a special type of split coupling called Erickson coupling is used. It is somewhat similar to a water-pipe union, but is used without gasket or ground joint.

Manual Bending

In any conduit job you will have to make bends of various shapes, such as right-angle or 90-degree bends, offsets, and saddles. For smaller pipe this is done with a bending tool which is commonly called a hickey.

The procedure illustrated in figure 8-3 is recommended as one method of making a right-angle bend in a length of 1/2-inch conduit using a hickey. If a 90-degree bend is to be made in a length of conduit at a distance of 20 inches from one end, the electrician must:

1. Mark off 20 inches from the end of the conduit.

2. Place the conduit hickey 2 inches in front of the 20-inch mark and bend the conduit about 25 degrees.

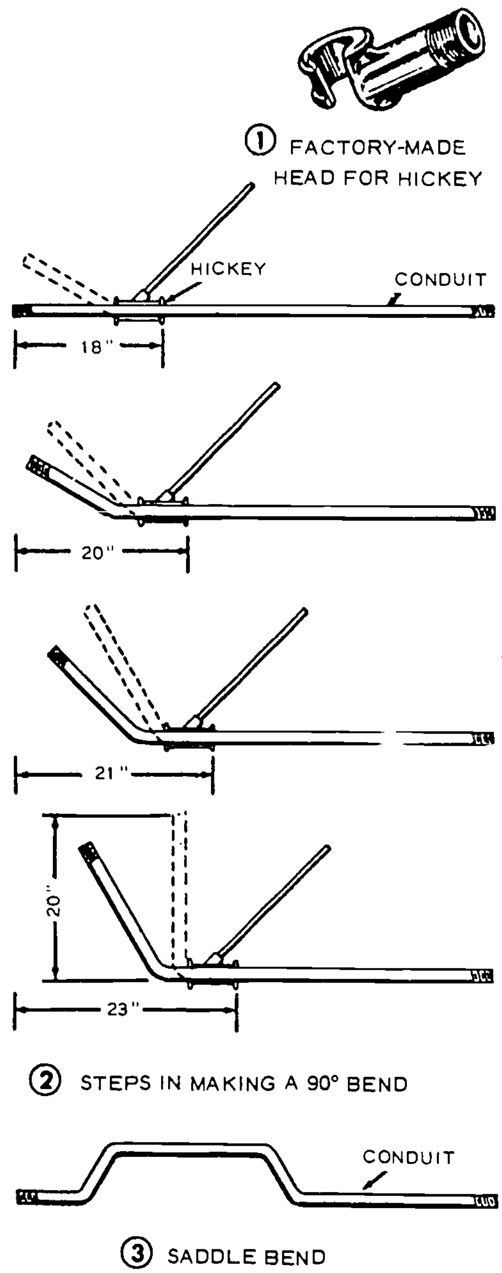
3. Move the bender to the 20-inch mark and bring the bend up to 45 degrees.

4. Move the bender about 1 inch behind the 20-inch mark and bring the conduit up to 70 degrees.

5. Move the hickey back about 2 inches behind the 20-inch mark and bring the bend up to 90 degrees.

When bending conduit beyond 90° never make a sudden, sharp bend which may cause flattening of the pipe. Make a bend in a series of gradual movements. Bend a small amount; then move the bender a short distance and bend again.

Miscellaneous conduit bends such as the saddle bend shown in figure 8-3 can be made more accurately if the contour of the bend is drawn with chalk on the floor and the bend in the pipe is matched with the chalk diagram as the bend is formed. Conduit in excess of 1 inch is usually bent by a hydraulic bender.



73.304

Figure 8-3.— Bending rigid conduit with a hickey.

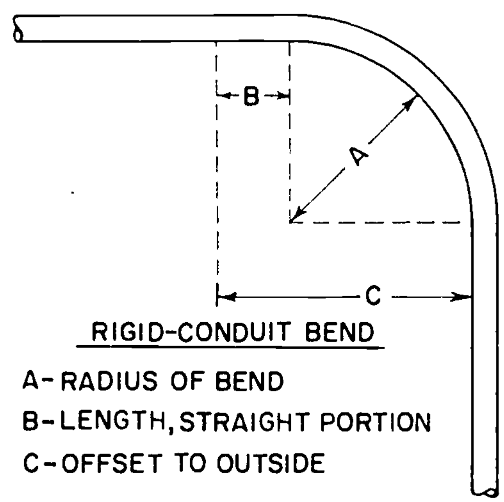
Hydraulic Bending

A hydraulic bender speeds conduit and pipe installations by means of a powerful force, applied smoothly to the pipe, resulting in accurate bends without kinks or damage.

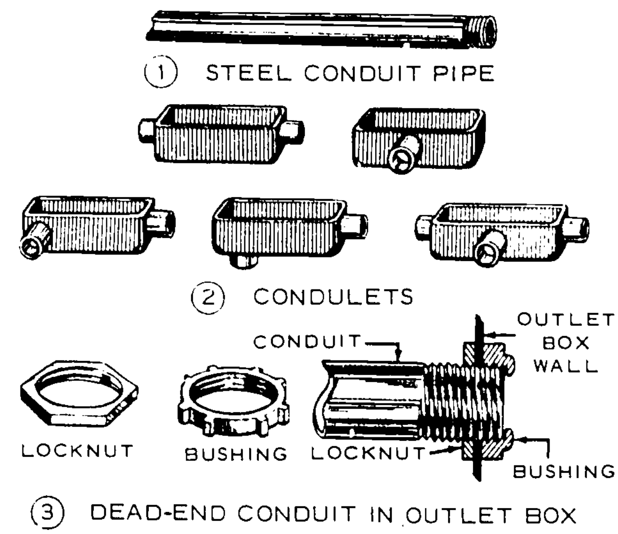
A portable hydraulic bender may be operated by a suitable electric motor, or manually by a hydraulic hand pump. A bending ram assembly which can be quickly disconnected completes the unit. For a single conductor which is not lead-covered, the bend must have a minimum radius of six times the inside diameter of the pipe; for lead-covered conductors the radius of a conduit bend must be at least 10 times the inside diameter of the conduit. Figure 8-4 illustrates what is meant by the radius of bend. Making a quick, neat bend is a job that requires a lot of practice.

Fittings

There are two types of fittings for conduit: the standard size outlet box (fig. 8-5, view 2) and the junction or pull box. The standard outlet box fittings are classified as type F and are used normally in exposed installations for receptacles or switches. The junction or pull box fittings are used to provide intermediate points in long conduit runs for pullthrough of wire or junctions for several conduit runs. Conduit fittings are not permitted in concealed installations where they will not be accessible. Boxes used with rigid conduit are supplied with removable knockouts. Bushings and locknuts are provided for attachment of the conduit to the boxes, as shown in figure 8-5, view 3.



73.17
Figure 8-4. — Dimensions of conduit bend.



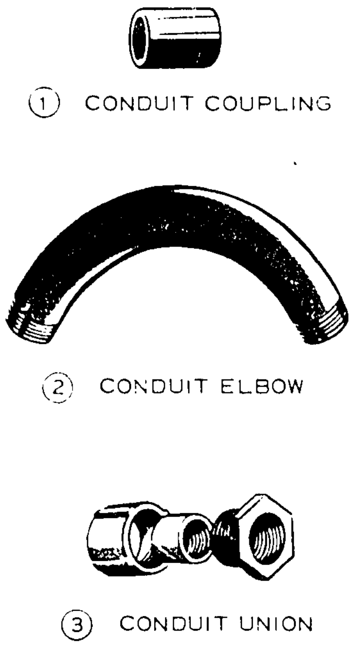
73.409
Figure 8-5. — Rigid conduit and fittings.

Boxes to be used in wet locations must have threaded hubs which the conduit is screwed into. Other accessories are shown in figure 8-6. The threaded coupling is furnished with each length of rigid conduit. Standard conduit elbows are manufactured for use where 90° bends are required. Unions permit the opening of a conduit at any point without sawing or breaking the conduit run.

Condulets are a convenient way of making bends, especially in conduit which will be exposed to the elements. However, a condulet must never be concealed in a wall or elsewhere, because the cover must always be accessible. Condulets may be used to reduce the number of bends made in a run of conduit. The NEC specifies not more than four 90-degree bends between pull boxes (NEC article 370-18) but a condulet may be used in place of a pull box.

The LB condulet shown in figure 8-7 is very convenient for sharp corners. The LB condulet can be opened at the back to allow the wire to be pulled without binding against the conduit wall. Be sure that covers are set on securely. For condulets exposed to the elements, place a gasket under the cover to ensure that it is watertight.

Neatness is a must in bending, conduit work, and any other electrical work. Bends which are



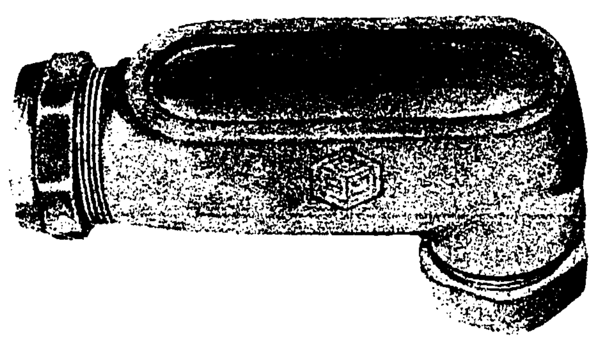
73.410
Figure 8-6.—Rigid conduit accessories.

not uniform detract from the appearance of the job. The method of securing conduit depends on its size and type. A one-hole strap is the type of fastener most frequently used. The manner of fastening depends on the material to which it is fastened. Hollow walls require toggle bolts: concrete or block walls require a lead anchor set in a drilled hole; steel construction requires a bolt set in a drilled hole.

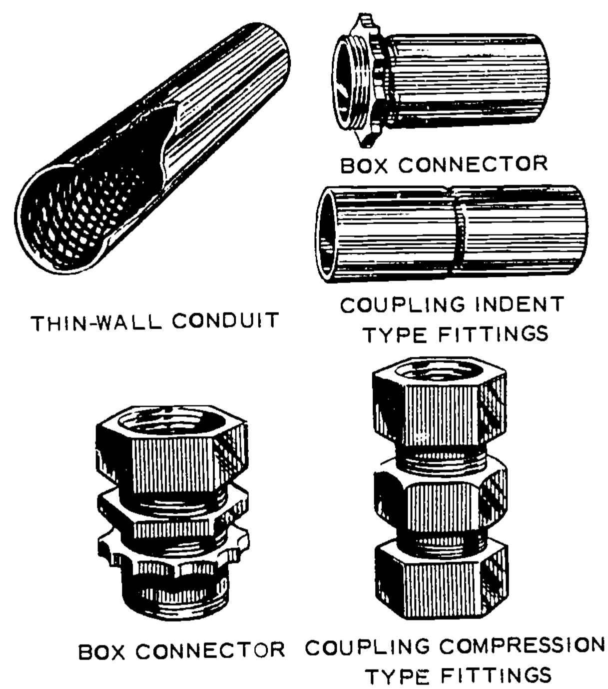
ELECTRIC METALLIC TUBING (THIN-WALL OR EMT)

Thin-wall conduit is a metallic tubing which can be used for either exposed or concealed electrical work. This conduit, as its name implies, has a thinner wall than rigid conduit but has the same cross sectional area as rigid conduit. It is available in sizes from 1/2 inch to 4 inches in diameter. All couplings and connections to boxes are threadless and are of either the clamp or compression type. Some common types are shown in figure 8-8. The compression type is waterproof. The indent and setscrew types are not waterproof.

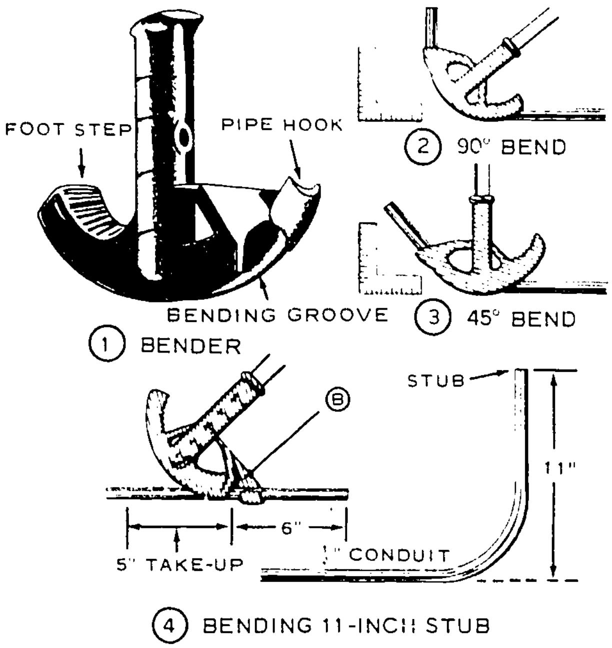
Extreme care must be used when bending metallic tubing to avoid kinking the pipe or reducing the inside area. The thin-wall conduit bender (fig. 8-9, view 1) has a cast steel head which is attached to a steel pipe handle approximately 4 feet long. It is used in the field to form thin-wall conduit into standard and offset bends. Benders are made for each size of conduit and must be used only on those sizes for which they are designed.



73.18
Figure 8-7.—LB condulet.



73.411
Figure 8-8.—Thin-wall conduit and fittings.



73.412
Figure 8-9.—Bending thin-wall conduit.

To bend conduit, first place the conduit on a level surface and hook the end of the bender under the conduit's stub end. Then, with the bending groove over the conduit and using a steady and continuous force, while firmly holding the conduit and bender with the body, push down on the handle and step on the foot step, bending the conduit to the desired angle. Takeup height is shown in figure 8-9, view 4. You can cut thin-wall conduit using a 32-teeth-to-the-inch hacksaw blade, keeping the cut at right angles to the axis of the pipe.

INTERMEDIATE METAL CONDUIT

Intermediate metal conduit is a conduit with a wall thickness less than rigid metal conduit but greater than that of EMT. It uses the same standard fittings as rigid metal conduit and has the same general application as rigid metal conduit, except that it must not be used in hazardous locations. Its lighter weight makes for easier handling and lower labor units (estimates) than rigid conduit. Because it has the same outside diameter as rigid metal conduit of the same size, it has greater interior cross sectional area. This does not permit the use of more conductors than can be used in the same size of rigid metal conduit but does make wire pulling easier.

PVC CONDUIT

Rigid polyvinyl chloride (PVC) conduit has been developed by many manufacturers. Some of the advantages of PVC conduit are: the light handling weight, high corrosion resistance, ease of installation, leakproof joints and easy wire pulling (due to the mirror-like walls). Refer to NEC, articles 347, 514-8, and 515-5 for installation requirements.

Joining PVC

Permanent joints are made quickly in PVC conduit by cutting the conduit with a handsaw or hacksaw and removing the burrs with a pocketknife. The surfaces to be joined are wiped clean and a light coat of solvent cement is applied to the inside of the coupling or fitting and outside of the conduit. After the conduit is inserted all the way into the fitting, it is given a quarter turn to ensure good distribution of the cement. Any excess is wiped off.

A variety of threaded PVC fittings is available from manufacturers. Their use is covered in article 370 of the NEC. Installation using the solvent-welding technique described in the previous paragraph, however, is preferred because the joints are water- and vaporproof.

Bending PVC

Bending of PVC conduit is accomplished very easily by application of heat from a hot-air, cold-air blower to a section of PVC rigid conduit. Gradual pressure is applied to form the bend desired. When the desired curve is achieved, the cold air from the blower is then applied to set the bend. Be sure to compensate for any spring back. Remember, too, that PVC conduit should be bent on a radius at least 10 times its diameter.

FLEXIBLE CONDUIT

Flexible conduit (also called Greenfield) is composed of a spirally wrapped metal band wound on itself and interlocked so that it makes a cylindrical metal flexible tube of high mechanical strength. Greenfield can be used in locations where rigid conduit is not adaptable. It is easily fished, requires no elbow fittings, and comes in diameters from 1/2 inch to 3 inches.

The only fittings required for Greenfield are squeeze type fittings for connecting the pipe to boxes. (See fig. 8-10.) A fine-tooth hacksaw should be used for cutting, and again the cut should be square.

Greenfield is available in two types: the standard unfinished-metal type, and a moisture-resistant type called sealtite, which has an outside jacket of latex or plastic. The moisture-resistant type is not intended for general use, but only for connecting motors or portable equipment in damp or wet locations where flexibility of connections is desired. It must be used with connectors approved for the purpose.

The standard metal Greenfield is used primarily for connecting motors mounted on sliding bases. It is also used for equipment which cannot be easily wired with rigid conduit and requires conduit which can be fished in walls or between the floor above and ceiling below. It is seldom used in wet or hazardous locations except as expressly permitted by the NEC.

WIRING TROUGHS

Wiring troughs are useful in any location where a large number of conduits enter a panelboard. One large conduit can be used to carry a number of conductors from the panel to the trough and smaller conduits branch out from the trough to the various circuits. The trough can also be used for feeders from the entrance switch to the panelboard. An example of how wiring troughs are used is shown later when service entrances are discussed.

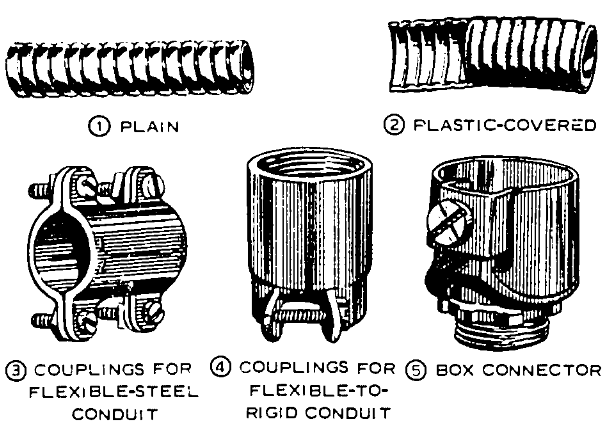


Figure 8-10.—Greenfield flexible conduit and fittings.

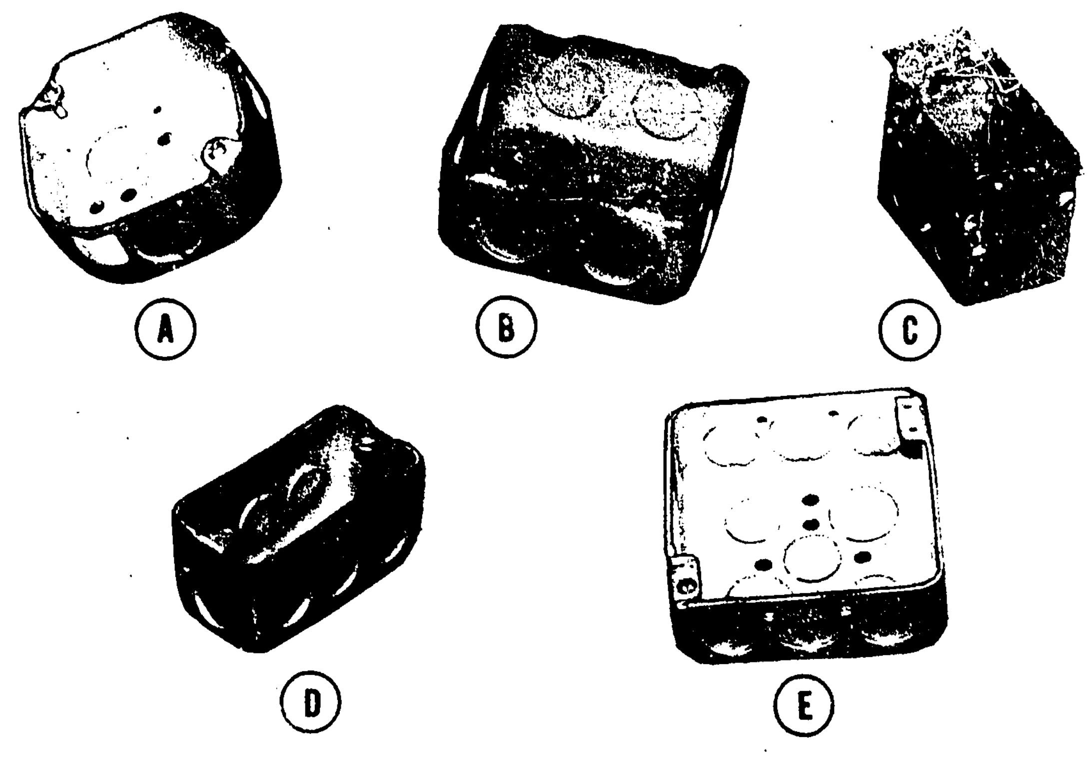
BOXES

A box is a container, set flush or nearly flush with the wall, floor, or ceiling, into which the outlet, receptacle, or switch will be inserted and fastened. A 4-in. octagon box used for ceiling outlets is shown in view A of figure 8-11. This box is made with 1/2-in. or 3/4-in. knockouts—that is, indentations which can be knocked out to make holes for the admission of conductors and connectors. View B shows a 4 11/16-in. square box used for heavy-duty installation, such as for a range or dryer receptacle. It is made with knockouts up to 1 in. in diameter. The box in view C is a sectional or gem box used for switches or receptacles. By loosening a screw you can remove a side panel, so that two or more boxes can be ganged (combined) to install more than one switch or receptacle at a location. View D illustrates a utility (called a handy) box, made with 1/2- or 3/4-in. knockouts and used principally for open type work. The box in view E is a 4-in. square box with 1/2-or 3/4-in. knockouts, used quite often for switch or receptacle installation. It is equipped with plaster rings having flanges of various depths, so that the box may be set in plaster walls of various thicknesses.

Besides the boxes shown, there are special boxes for switches when you have more than two switches at a location. These are called conduit gang boxes, and they are made to accommodate 3, 4, 5, or 6 switches. Each size has a cover made to fit.

A ceiling box may be fastened to a wooden header set between the ceiling joists, or it may be fastened to a bar hanger as shown in figure 8-12.

The NEC requires that outlet boxes be 1 1/2 in. deep, except when the use of a box of this depth "will result in injury to the building structure or is impracticable," in which case a box not less than 1/2 in. deep may be used. Switch boxes range in depth from 1 1/2 in. to a maximum of 3 1/2 in. The 2 1/2 in. depth



73.15

Figure 8-11.—Types of outlet, receptacle and switch boxes.

is the most widely used. The 1 1/2 in. depth boxes are used when two boxes in two different rooms happen to come back-to-back in the wall separating the rooms.

Nonmetallic boxes are made of plastic material and are used with nonmetallic-sheathed cable. Many types are available with mounting brackets or nails for installing directly on timbers in buildings. These boxes are of one-piece construction and cannot be ganged, but readymade 2-gang and 3-gang boxes are available. Connectors are not needed at the box but the cable must be supported within 8 in. of the box on new work.

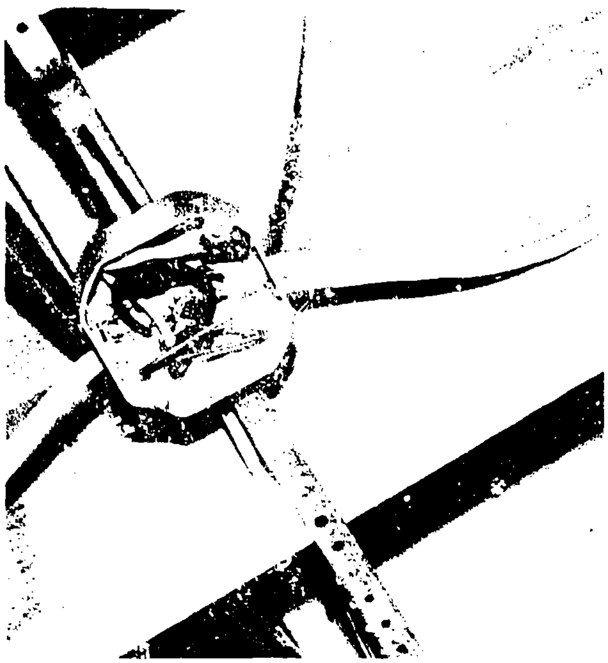
To locate outlet, receptacle, and switch boxes you follow the electrical floor plan. Assume you are working on a new building in which all wiring will be concealed by wall, ceiling, or floor covering. The NEC requires that the outside edges of outlet and switch boxes without flush plates NOT be recessed more than 1/4 in. below the surface of the finished wall. Boxes having flush plates must not project beyond the finished wall surface. Wall outlets are to be located the following distances above finished floor surfaces: duplex receptacles, 12 in.; toggle switches, 48 in.; wall fan receptacles, 78 in.; overcounter receptacles, 46 in. All these measurements are from the finished floor surface to the middle of the receptacle. The usual way to mount a wall box in a frame wall is on a wood header inserted between studs.

For exposed wiring installed in a building after completion of the wall finish, the procedure for securing boxes varies according to the wall or ceiling surface material. Boxes are fastened to a wood surface with wood screws; for plasterboard or plywood, toggle bolts are better; for concrete you must drill holes for setting lead anchors.

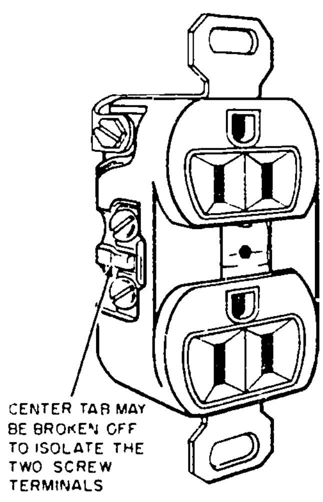
RECEPTACLES

Receptacles used in interior wiring are discussed below in the order of their frequency of use.

A convenience outlet (fig. 8-13) is a duplex receptacle with two vertical or T-slots and a



73.16
Figure 8-12. — Ceiling outlet box on bar hanger.



73.28
Figure 8-13. — Duplex convenience outlet.

round contact for the ground. This ground is connected to the frame of the receptacle, and is grounded to the box by way of the screws that secure the receptacle to the box.

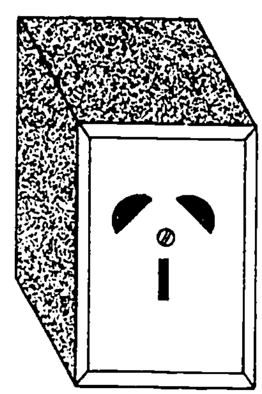
When you desire to have the two outlets on a receptacle supplied by two separate power sources, break the center tab between the two screw terminals on each side. Then, wire the same as you would single outlets. Most floor receptacles are single receptacles with two vertical or T-slots.

A range receptacle (fig. 8-14) may be a surface type or a flush type. It has two slanted contacts and one vertical contact, and is rated at 50 amps. Receptacles for clothes dryers are similar, but are rated at 30 amps. Range and dryer receptacles are rated at 250 volts, and are used with three-wire, 115/230 volts, two hot wires and a neutral. A receptacle for use with an air-conditioner taking 230 volts is made with two horizontal slots and one round contact for the ground.

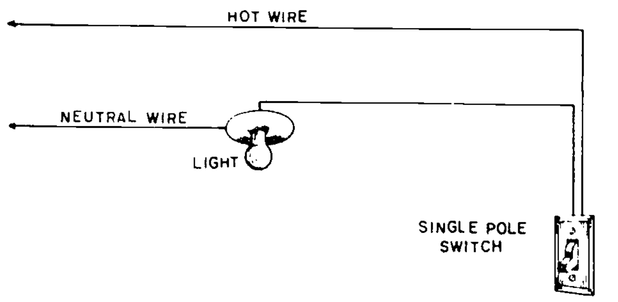
SWITCHES

For interior wiring you use single-pole, 3-way, or 4-way toggle switches. Most of the switches you use will be single-pole, but occasionally you will have to install a 3-way system, and on rare occasions a 4-way system. Still another system of switching, called the low-voltage system, is coming into use.

A single-pole switch is a one-blade, on-and-off switch which may be installed singly or in multiples of two or more in the same metal box. (Boxes were explained earlier in this chapter.) In wiring a single-pole switch, connect the colored wires to the two contacts on the switch, the switch being always in series with the hot wire. Figure 8-15 shows a single-pole switch circuit.



73.29
Figure 8-14. — Range receptacle.



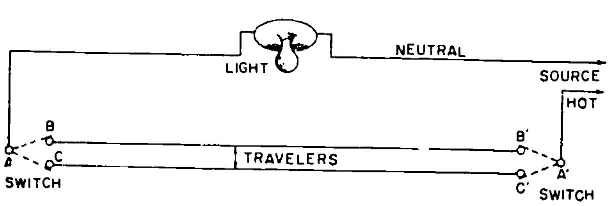
73.24
Figure 8-15.—Single-pole switch circuit.

In a 3-way switch circuit there are two positions, either of which may be used to turn a light on or off. The typical situation is one in which one switch is at the head of a stairway and the other at the foot. Figure 8-16 shows how the circuit functions.

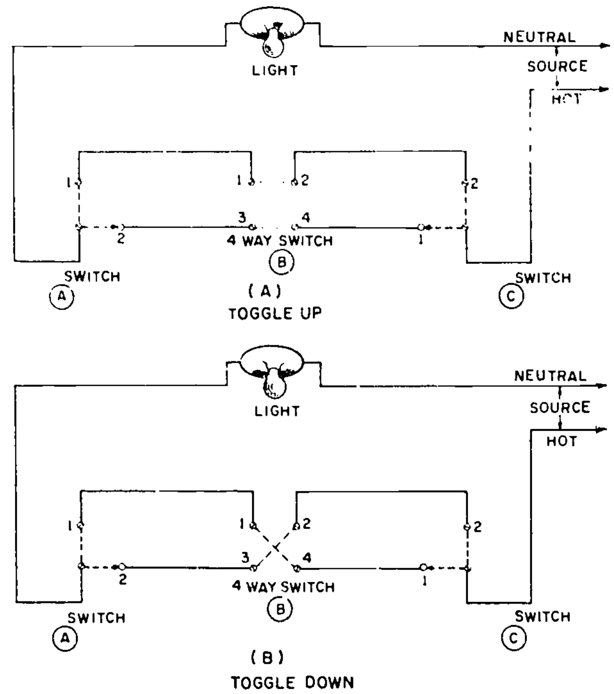
Terminals A and A' are the common terminals, and switch operation connects them either to B or C and B' and C', respectively. Either switch will operate to close or open the circuit, turning the lights on or off.

By tracing the circuit in figure 8-16 from the source, you can see that the hot wire goes to the first switch, through the closed switch blade to the other switch by way of the traveler, and through this switch to the light. By changing the position of either of the switches, the circuit is broken.

A 4-way switch is an extension of a 3-way circuit by the addition of a 4-way switch in series with the two traveler wires. Figure 8-17, view A shows how a 4-way circuit is wired. By tracing this circuit from the source you observe the hot wire connected to switch (C) passing through position 1, which is closed. The hot wire continues to point 4 on the 4-way switch (B). At this time the toggle on switch



73.25
Figure 8-16—Three-way switch circuit.



73.26
Figure 8-17.—Four-way switch circuit.

(B) is in the UP position and contact is made from point 4 to point 3. The hot wire continues on through the traveler to switch (A), and through position 2 (which is closed) to the light.

Suppose, now, that you want to turn the light off at 4-way switch (B). By putting the toggle in OFF (down) position you change the switch blades from point 1 to 2 and 3 to 4 to points 1 to 4 and 2 to 3. (See fig. 8-17, view B.) If you now retrace the circuit from switch (B) to switch (A), you will find that it goes from point 4 to point 1 on switch (B) and through the traveler to switch (A), where the circuit is broken by the blade in open position.

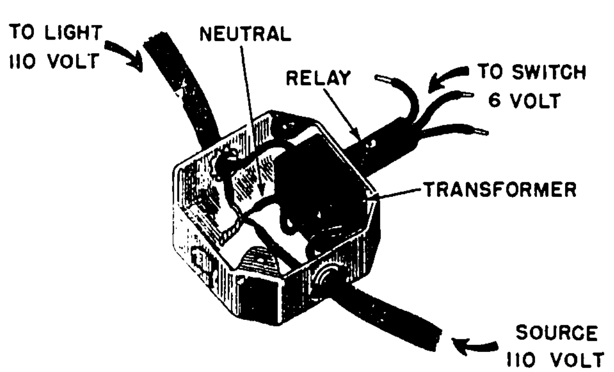
Most 4-way switches have a wiring diagram on the switch body. Some, however, have the diagram on the carton the switch is packed in. This diagram must be preserved. If it gets lost you will have to use an ohmmeter or battery to trace the movement of the blades when you change the position of the toggle.

Note that 3-and 4-way switches may be used as single-pole switches, and 4-way switches may be used as 3-way switches. Some activities may install all small-wattage, 4-way switches for all lighting circuits, to reduce their inventories. However, 3- and 4-way switches are usually larger than single-pole switches and take up more box room. The size of a switch depends on its ampacity (rated maximum amperage). The ampacity and maximum allowable voltage are stamped on the switch, and must be considered when ordering equipment for the job.

Low-voltage wiring is a switching system which employs a transformer and low-voltage relay. A low-voltage conductor (three No. 18 AWG wires) is used from the outlet to the switch box instead of conduit or Romex. Some systems use a master transformer to reduce the voltage from 110 volts to 6 volts, but one system uses a combination transformer. (A relay is a protective device which opens a circuit when current in a line exceeds the rated value of the relay at the outlet box.) A combination transformer ensures that only one light is affected in case of transformer failure.

The transformer-relay combination is installed in the outlet box for the light being controlled, with the transformer inside the outlet box and the relay protruding outside through a knockout, as shown in figure 8-18.

In the low-voltage system as many switches as are required can be installed for any given light, or a master switch can be installed to turn on as many as eight lights simultaneously.



73.27

Figure 8-18.—Low-voltage relay and transformer.

There is no necessity for 3-way or 4-way switches, because the switches are connected in parallel, and the movement of the switch toggle in one direction pulls the relay one way (off the circuit) and energizes the light. A movement of the toggle in the other direction pulls the relay the opposite way (into the circuit) and breaks the circuit.

EXPLOSION-PROOF FITTINGS

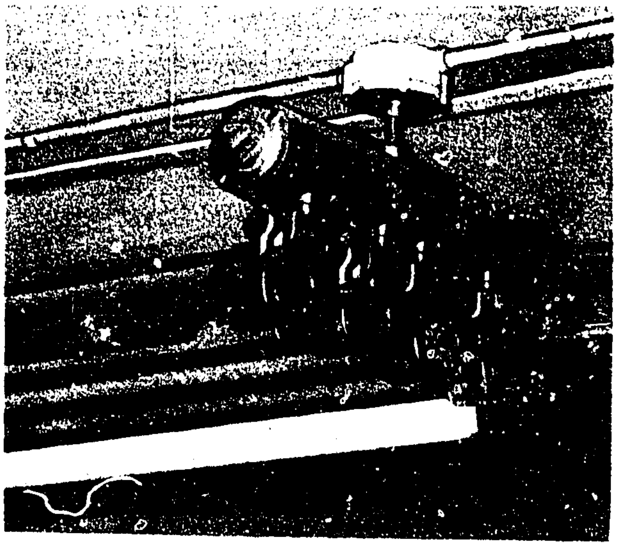
In locations specified by the NEC (articles 510 through 517) as explosion-hazardous, you must install explosion-proof fittings. Locations are classed by number in descending order of danger: class 1, division 1, highly hazardous; class 1, division 2, slightly less hazardous; and so on.

As an example of explosion-proofing; in a gasoline filling station the pump island is classed as class 1, division 1. All conduits in this area must be sealed with a special sealing fitting, and on conduit for lights above the pumps the sealing fitting must be located at a height of not less than 4 ft above the driveway surface. No junction boxes (explained in NEC article 370-18) or condulets may be used in the pump area. Conduits running from pumps to panels in the building must be sealed not less than 18 in. above the building finished floor to avoid fumes from the gasoline pumps. An approved seal must also be installed on any conduit entering or leaving a dispensing pump or other enclosure on the pump island.

Inside the building of a gasoline station the class 1, division 1, space extends 18 in. above the floor. Space above the 18-in. level is classed as class 1, division 2.

Paint spray booths are listed as class 1, division 1, and therefore all fixtures, exhaust fans, air compressors, or other electrical appliances located in such booths must be explosion-proof, as well as all switches, convenience outlets, and motor starters.

Figure 8-19 shows an explosion-proof fluorescent lighting fixture for installation in a paint spray room. In this fixture the fluorescent tubes are sealed in a larger glass tube. The four tube seal ends can be seen in the figure. The ballast (explained in NEC article 410, part P) is enclosed in the container above the tube seals.



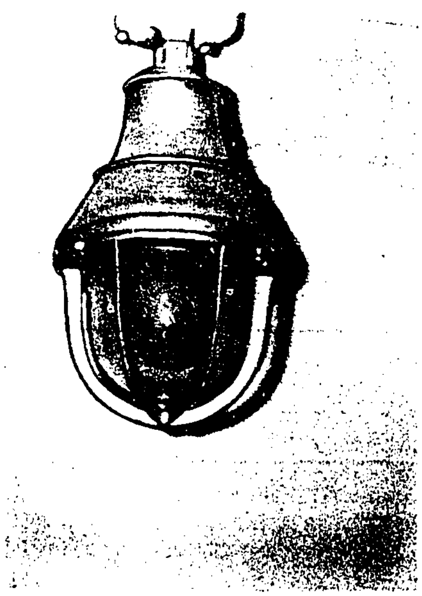
73.19
Figure 8-19.—Explosion-proof fluorescent fixture.

Figure 8-20 shows an explosion-proof incandescent lighting fixture; figure 8-21, an explosion-proof on-and-off switch for lighting.

When the interior wiring system has been completely installed, make an overall inspection to be sure that good installation practices have been observed and all connections are correct. While making this check, don't forget neatness. Make sure that ground connections are tight and that ground wire is protected against injury. Be sure that all connections in entrance switch and panelboards are tight. See that all metal noncurrent-carrying parts of portable equipment are grounded.

INSTALLING THE SERVICE

The term "service" means, in general, the electrical system which brings the power from the pole or other point on the powerline to the point in the building from which it is distributed to the building circuits.



73.20
Figure 8-20.—Incandescent explosion-proof fixture.

73.21
Figure 8-21.—Explosion-proof on-and-off lighting switch.

The service for a building consists of two parts: the service conductors and the service equipment. The service conductors are divided into service drop conductors and service entrance conductors. The SERVICE DROP CONDUCTORS are run from the pole to the building. The SERVICE ENTRANCE CONDUCTORS connect the drop conductors at a point outside the building and must be run in rigid conduit to the service equipment inside the building.

The service equipment consists of circuit breakers, switches, and fuses. This equipment is located near the point of entrance of the supply conductors to a building, and constitutes the main control and means of cutoff for the electrical supply to that building.

SERVICE DROP CONDUCTORS

Service drop conductors may consist of an approved multiconductor cable or they may be open single conductors. In either case they must have thermoplastic, rubber, or other weatherproof insulation, except that a grounded conductor may be uninsulated if the maximum voltage to ground of any conductor does not exceed 300 volts. The current-carrying capacity of the service drop conductors must be sufficient to ensure that ample current for the prospective maximum load may be conducted without a temperature rise to a point high enough to damage the insulation. Obviously, the conductors must also have adequate mechanical strength. The NEC specifies No. 8 AWG wire as the minimum size, except that in special cases No. 12 may be used.

SERVICE ENTRANCE CONDUCTORS

Service entrance conductors in the Navy are single conductors run in rigid conduit; in civilian construction they may consist of an approved type of service entrance cable. Conductors also must have rubber or thermoplastic insulation, except that a grounded conductor may be uninsulated if the maximum voltage to ground of any conductor does not exceed 300 volts.

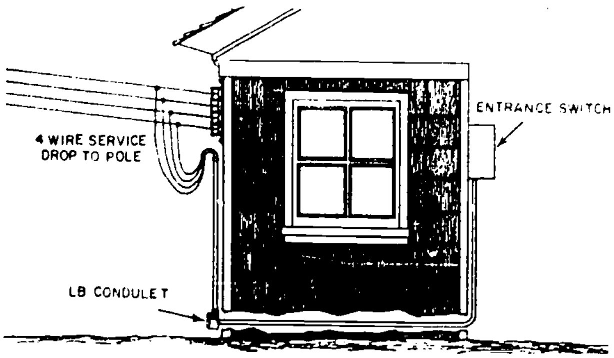
The NEC specifies No. 6 AWG wire as the minimum size conductor to be used for service entrance, except that in special cases and by special permission, No. 8 wire may be used. For a Navy man, special permission means that of higher authority. In civilian work (in most civilian communities the NEC has been incorporated into the building laws) it means that of the community's building inspectors.

Table 1 of the NEC indicates the maximum number of conductors of a given size to be used in rigid conduit for new work. Let's assume you are going to use No. 6 wire with Type THWN insulation. Using three wires (the normal number for service entrance) you see that you can use 1-inch conduit. The conduit must be continuous from the weatherhead (point where the wires enter the conduit) to the entrance switch except when a condulet (fig. 8-22) is used in place of a bend.

The conductors must be continuous from the weatherhead outside the building to the connections in the entrance service switch—meaning that no splices between these points are allowed. However, a connection is permitted,

Table 8-1.—Circuit conductor wire sizes for various motors

MOTOR HP	SINGLE-PHASE AMPS AT 110 V	WIRE SIZE (AWG)	AMPS AT 220 V	WIRE SIZE (AWG)	3-PHASE AMPS AT 220 V	WIRE SIZE (AWG)
3/4	14	12	6.9	14		
1	16	12	8	14	3.5	14
1 1/2	20	10	10	14	5	14
2			12	14	6.5	14
5			28	8	15	12
7 1/2			40	6	22	10
10					27	8
15					40	6



73.8
Figure 8-22. — Service entrance with condulet.

when properly enclosed, where an underground service conductor enters a building and is to be extended to the service or meter in another form of approved service raceway or service cable.

When the service is run underground, the conduit must be continuous from the pole or underground vault to the service switch. If the conduit enters the building through a concrete floor, a conduit coupling must be installed in the conduit line with the top of the coupling flush with the finished floor surface. The advantage of this is that spare conduits can be installed in the concrete floor and a plug screwed into the coupling, making a flush job. Also, if the wiring were to be removed for some reason, the open conduit could be removed from the coupling and a plug screwed into the same.

ENTRANCE SWITCHES

A service entrance switch provides a means of disconnecting the service conductors from the supply source. It may consist of a single manually operated switch or circuit breaker. It must be marked to show whether the contacts are in an open (OFF) or closed (ON) position, as illustrated in figure 8-23.

The neutral conductor must not be run straight through the service switch, without a means of disconnection. Therefore, a screw or bolted lug on the neutral terminal block should be provided for disconnecting the neutral conductor from the interior wiring system.

The NEC sets a minimum size for entrance switches at 60 amp for the fuse type and 50 amp

73.10
Figure 8-23. — Entrance switch marked to show open (OFF) and closed (ON) positions.

for the circuit breaker type. A circuit breaker is a protective device which automatically opens the circuit, rather than burning out like a fuse, when the amperage exceeds that rated for the circuit breaker.

However, the NEC recommends a minimum size of 100-amp service for individual residences. An exception is that where not more than two 2-wire branch circuits are installed, a 30-amp entrance switch may be used.

No overcurrent device may be inserted in a grounded conductor except a circuit breaker which will simultaneously open all conductors of the service. EVERY ungrounded conductor must be provided with overcurrent protection.

Switches used for entrance equipment must be of an approved type. An approved type is usually a quick make-and-break type with an interlocked cover which can't be opened when the switch is in the ON position. The service conductors must be connected to the disconnecting device by pressure connectors, clamps, or other approved means; a solder lug or other type of soldered connection cannot be used.

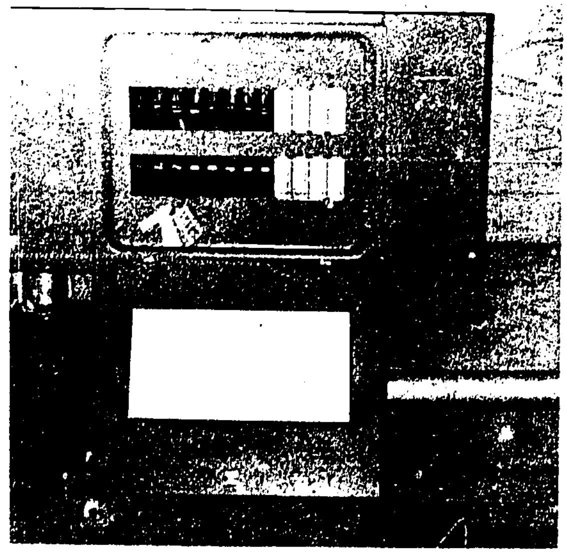
DISTRIBUTION PANELS

A panelboard is defined by the NEC as "a single panel or group of panel units designed for assembly in the form of a single panel including buses (buses and busways are explained in articles 364 and 384-21 of the Code) and with or without switches and/or automatic overcurrent protective devices for the control of light, heat, or power circuits of small individual as well as aggregate capacity, designed to be placed in a cabinet or cutout box and placed in or against a wall or partition and accessible only from the front."

As a Construction Electrician, you will be concerned mostly with the breaker panel for both light and power. (See fig. 8-24.) The breaker panel uses a thermal unit built into the switch. The breaker is preset at the factory to operate automatically at a predetermined ampere setting. It may be reset to the ON position after a short cooling-off period.

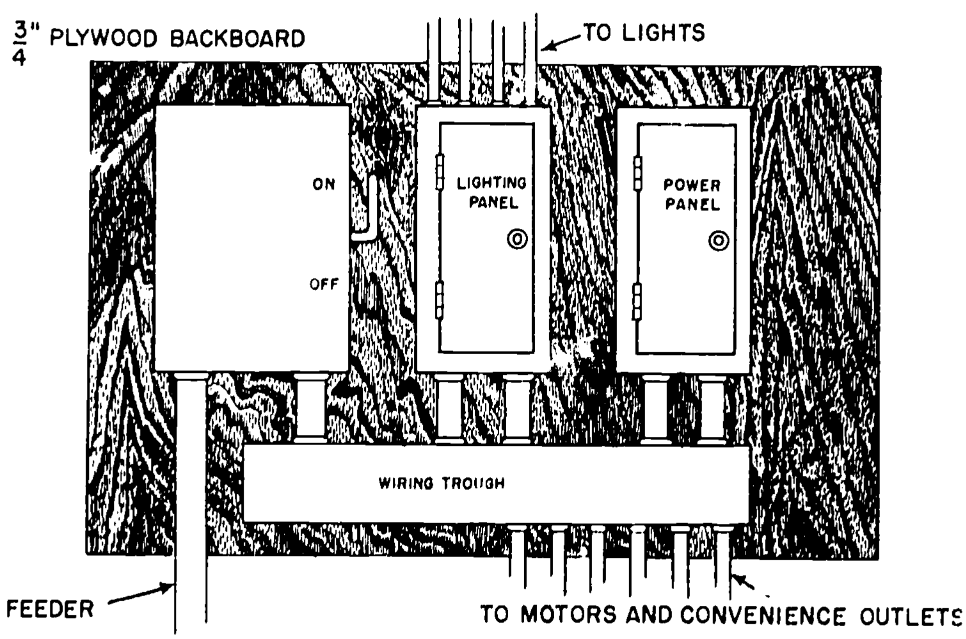
Lighting panels are normally equipped with 15-amp single-pole automatic circuit breakers, while the power panels may have 1- 2- or 3-pole automatic circuit breakers with a capacity to handle the designated load. Figure 8-25 shows a typical layout for an entrance switch, lighting panel, and power panel.

In most buildings the entrance switch and panelboards can be mounted close to each other.



73.11

Figure 8-24.— Lighting panel.



73.12

Figure 8-25.—Representative layout for entrance switch, lighting panel, and power panel.

When wiring a building that has been built previously, the best way to mount the switch and panels is to mount a sheet of plywood for a backing board. The board should be large enough to accommodate all of the equipment, be a minimum of 3/4 in. thick, and be securely fastened to the wall with wood screws, lead anchors, or toggle bolts, depending on the type of wall. The switch and panels can then be fastened to the backboard with wood screws.

If you are working in a newly constructed building where only the framework has been erected, it will be a simple matter to arrange for a concealed installation. One point to remember is that there are two types of switches and panels. The recess or flush type has a front flange that extends beyond the edges of the cabinet to cover the rough edges around the cabinet where the finish wall has been cut. Also, the flush type switch as a front control for operating the switch. The surface type switch and panel has a front cover that does not extend beyond the sides of the cabinet, and the switch may be side-operated or front-operated.

In locating panels, you must follow certain basic requirements. The panels must be placed where service and maintenance can be easily performed; they should not block any passage that is supposed to be open; they must not be in a place where they might be exposed to corrosive fumes or to dampness; and they should be located as near as possible to the center of the electrical load.

The circuits controlled at the panelboard must be clearly indicated. List them numerically, from top to bottom, with the odd numbers on the left. Put this list (called a catalog) in the slot provided for it, as shown in figure 8-24. If possible, provide for extra circuits in the new panel to accommodate future additions.

NEUTRAL WIRE

To understand the purpose of a neutral wire, bear in mind that the path traveled by electricity is always from the source around the circuit and back to the source. As the current follows this path, it energizes the fixtures and/or appliances that are connected into the circuit. You can see, therefore, how essential it is to ensure current return.

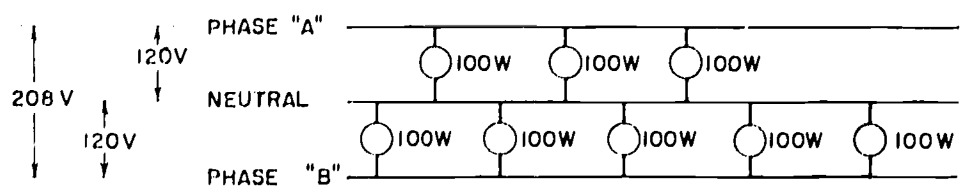
Generally speaking, the fixtures can be considered as resistances in series with the hot wires. In a balanced circuit, one hot wire carries the current to the load, while the other carries it back to the source.

The neutral wire ensures current return in an UNBALANCED circuit, as shown in figure 8-26. Here there are two hot wires and a neutral. There are three lamps connected across one hot wire and the neutral, and five lamps connected across the other hot wire and the neutral. These lamps occasion a current flow of approximately 1 ampere per lamp. It follows that the flow is 5 amps in one phase and 3 amps in the other—meaning that the circuit is unbalanced, with an unbalanced load of 5 minus 3, or 2 amps.

If each phase carried three lamps, the circuit would be balanced. But because there are two extra lamps in one phase, the neutral wire must pick up the extra load and return it to the source.

Why must the neutral have the same size as the hot wires? In this case, with all the lamps on, it must handle only 2 amps, whereas the hot wire in phase B must handle 5 amps. If the lamps in phase A were all turned off, the neutral would have to handle the full 5-amp return from phase B.

A motor in a circuit usually causes an unbalanced circuit. A motor operating on 220



73.14

Figure 8-26.—Use of neutral wire in unbalanced circuit.

volts single-phase does not have a neutral wire to aid the balance. Therefore, when a motor of this type is connected across two phases, the other phase should be given enough extra lighting load to balance the load as nearly as possible. Perfect balance is possible in theory, but not in actual practice.

With a 4-wire system, one neutral wire can be used for three circuits, provided the three are connected to opposing phases. Never use one neutral wire for two circuits connected to the same phase.

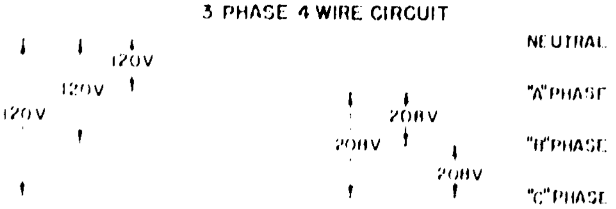
The NEUTRAL wire in a wiring system must not be confused with the equipment ground wire. The neutral wire should have white or light grey insulation; the equipment ground wire, if insulated, will always have green insulation. However, an equipment ground wire may be uninsulated.

In a 4-wire system (fig. 8-27), one of the wires is always a neutral wire, but in a 3-wire system there may or may not be a neutral wire. In a 3-wire system you may have a 3-phase circuit (3 live or hot wires), or you may have a single-phase circuit (2 hot wires and a neutral).

GROUNDING

The two types of grounds used are the system ground and the equipment ground. The system ground consists of grounding the incoming neutral wire as well as the neutral wires of the branch circuits. The equipment ground consists of grounding the metal parts of the service entrance, as well as the service entrance conduit. The equipment ground also includes grounding switchboard frames, motor, and similar equipment.

The usual method of grounding is to attach the grounding wire to a cold water pipe of the underground water system. If an underground water system is not available, driven grounds are used. Grounding systems are further discussed in chapter 9.



73.13

Figure 8-27. Four-wire system.

LOCATING AND INSTALLING CONDUCTORS

When the service switch, panelboards, and conduits have been installed, you are ready to pull in the wires. The electrical print or plan shows the number of wires to be pulled into each individual conduit. Remember that there must always be a neutral wire in any lighting or convenience outlet circuit.

Lighting fixtures and convenience outlets are connected between a neutral and a hot wire, with the wall switches connected in series with the hot wire. Any solid color except white or green can be used for the hot wire, except that in switch leg wiring using cable, the return leg must be black. The neutral wire is always white, and equipment grounds always green, if insulated. The accepted wire color code is in NEC article 210-5.

Wires are pulled through conduit with a narrow steel tape called a fish tape. Fish tapes come in various thicknesses; on most jobs you will use the small 1/8 by 1/16 in. size.

Start this tape through the conduit at an outlet box or panelboard, as the case may be, and keep pushing the tape until it emerges at the next opening or outlet box. You secure the wires to a hook on the fish tape by removing about 3 in. of insulation from the wires and bending the bare wires over the hook. Make a few wraps of friction tape over this connection, to prevent the wires from slipping off and to provide a smooth pulling surface. In some cases you may have to put talc or a lubricant called pulling compound on the wires. Never use oil or grease for this purpose, because these substances will deteriorate the insulation.

Pull the tape and wires back through the conduit. If possible, have a man at the point where the wires enter, to keep out kinks or twists. Where wires pass through an outlet box without being tapped, pull enough wire to continue on through without making a splice, to eliminate extra splices in the box or opening.

When the wires have been pulled in throughout the conduit system, connect the proper wires to the various fixtures and outlets. Do any necessary splicing at the same time. During splicing, remember that white wires connect to white, except for Romex cable switch runs, and other colors to the same colors. In splicing joints, always be sure the joint is well soldered and taped with rubber or friction tape—or, in some places, you may use a plastic electrical tape which does not require a cover of friction tape.

Another way of insulating splices is to use an insulated wire connector, called a wire nut (fig. 8-28, view A). You screw this device onto the bare end of a conductor. Wire nuts do not require tape if the conductor ends are cut short enough to prevent them from extending outside the nut.

A wire nut is but one type of solderless connector. Another type is shown in figure view B of figure 8-28. It grips the wires like a vise, producing such good metal-to-metal contact that it is unnecessary to use solder. Apply the connector to the wires, and then cover the joint with tape. Of course, you must prepare the wire ends just as you would for a soldered splice.

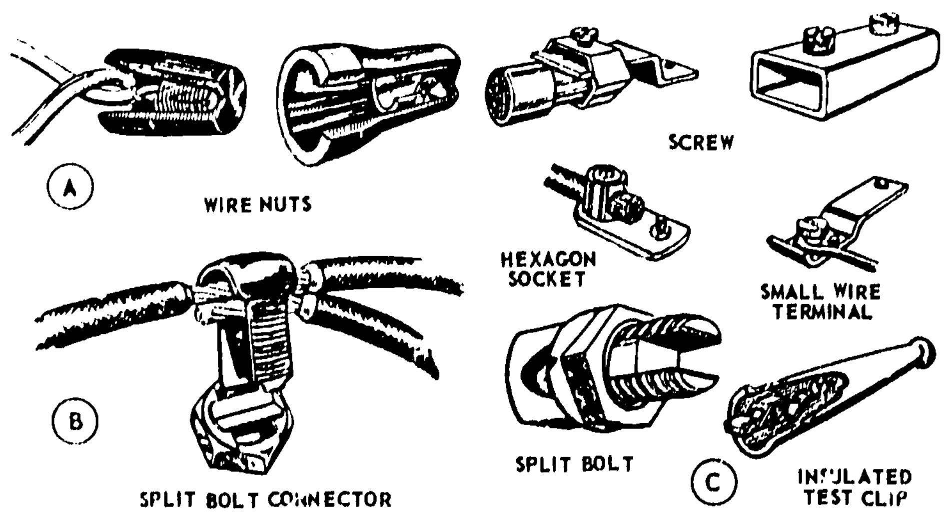
When installing Romex or BX, make sure the conductors do not come in contact with metal pipes, and see that they are supported properly, with no sag between supports. Exposed wiring in basements or attics is best protected by running the wire alongside joists or rafters. Where wires run across these timbers, you can run them through holes bored in the timbers. However, figure 8-29 shows how wire can be run across timbers on a running board.

Flexible cords on portable equipment must never be subjected to mechanical strain. They must be kept as short as possible. All cords must be 3-wire, with the third wire grounding the equipment on one end and terminating at the grounding screw in a 3-wire grounding attachment plug.

MOTOR BRANCH CIRCUITS

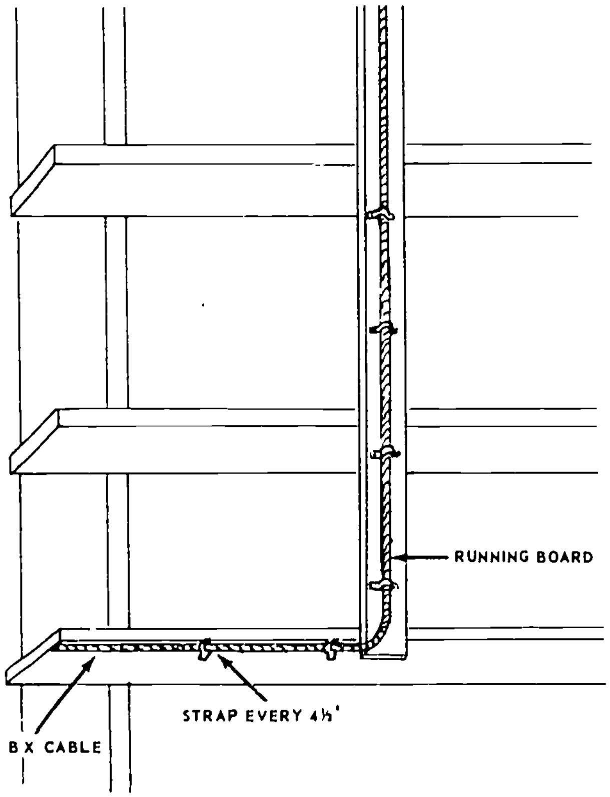
As a CE you will frequently have occasion to wire in, connect, and service motors of various sizes and voltages. A motor branch circuit consists of the following elements: circuit conductors, overcurrent protective devices, means for disconnection, controller, and motor running protection.

The circuit conductors are the wires from panelboard to motor. Overcurrent protective devices protect the motor, controls, and wires against any overloads caused by grounds or shorts. The means of disconnection separates motor and controls from electricity source when adjustment, maintenance, or repair work is being done. The controller starts, stops, and reverses



73.305

Figure 8-28. — Cable and wire connectors.



73.23
Figure 8-29.—Wires run across timbers on a running board.

the motor. Motor running protection is provided by overcurrent protective devices which protect motor, controls, and wires against damage caused other than by grounds and shorts

The circuit conductors may be feeding current to a motor of less than 1 hp. or to one with hp in the hundreds. The type of insulation used will depend on moisture and temperature conditions, and also on the danger of mechanical injury. The size of conductor will be determined on the basis of 125 percent of the full-load current of the motor. Table 8-1 gives you an idea of the wire size for a given motor hp and a given voltage.

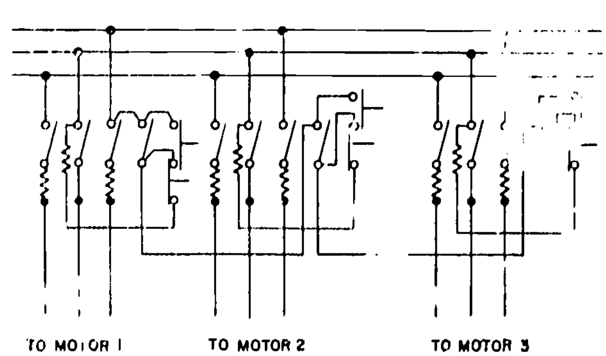
The disconnecting means for most motors is either a motor circuit switch or an air circuit breaker. It must be located within 50 ft of and visible from the motor, and must be equipped with a device for locking in OFF position. In every case the disconnecting device must be one which opens all ungrounded conductors instantly. It may also open the grounded wire, provided that it opens all wires simultaneously. It must disconnect both motor and controller, and may be installed in the same case with the controller.

For portable motors, the attachment plug and receptacle are sufficient means for disconnection. For stationary motors of 1/8 hp or less, the branch circuit overcurrent device is sufficient.

Motor controllers may be manual or automatic. For smaller motors a general-purpose switch or circuit breaker may be used. For larger motors and three-phase motors, automatic controllers give better service. An automatic controller can be remotely controlled by pushbutton, and for machinery motors the pushbutton can be installed convenient to the operator's station. This type of connection can also be used to interlock different motors, as in a system of conveyor belts. Figure 8-30 shows an interlocking system for three motors. Motor 1 must be running before motor 2 can be started, and motor 2 must be running before motor 3 can be started.

Overcurrent protection devices may be fuses or circuit breakers, used to protect the conductors against overloads of current greater than normal starting current. These devices also protect the motor controller, which cannot handle amperage higher than that which is normal to the motor.

If fuses are used, one must be placed in each ungrounded wire of sufficient capacity to



73.31
Figure 8-30.—Interlocking controls for three motors.

allow for motor starting current. A device other than a fuse must be capable of opening all ungrounded wires feeding a circuit.

MOTOR overload protection is required to protect against overload caused other than by a short or ground in the motor branch circuit. After a motor has come up to full speed, and is operating at its normal rated amperage, the equipment driven by the motor, because of a temporary overload or some other cause, may require more power than the rated hp of the motor. To deliver this extra power, the motor must consume greater-than-normal amperage. This type of overload can be safely carried for a short interval, but if it continues too long the motor will be damaged.

For example: Suppose something causes a fuse in a three-phase circuit to blow. The motor will try to continue running on a single phase. This will cause a much higher than normal amperage to flow through conductors and controller. However, a motor current protection device in the motor or controller will open all conductors to the motor.

Automatic controllers have such a device built into the controller. Some small motors have overload devices built into the motor.

INTERIOR WIRE SPLICES

The way you splice or join conductors together is one indication of your competency as an electrician. An electrical system is only as good as its worst splice. A good splice must have the same mechanical strength and electrical conductivity as the wires it joins together. A spliced wire must be as good a conductor as a continuous wire.

The best wiring practice is to run continuous wires from the service box to the outlets. UNDER NO CONDITIONS SHOULD SPLICES BE PULLED THROUGH CONDUIT. SPLICES MUST BE PLACED IN APPROPRIATE ELECTRICAL BOXES.

The following observations apply to electrical soldering:

1. Soldering a splice helps to protect it from corrosion.

2. Rosin is the only flux used in soldering electrical connections.

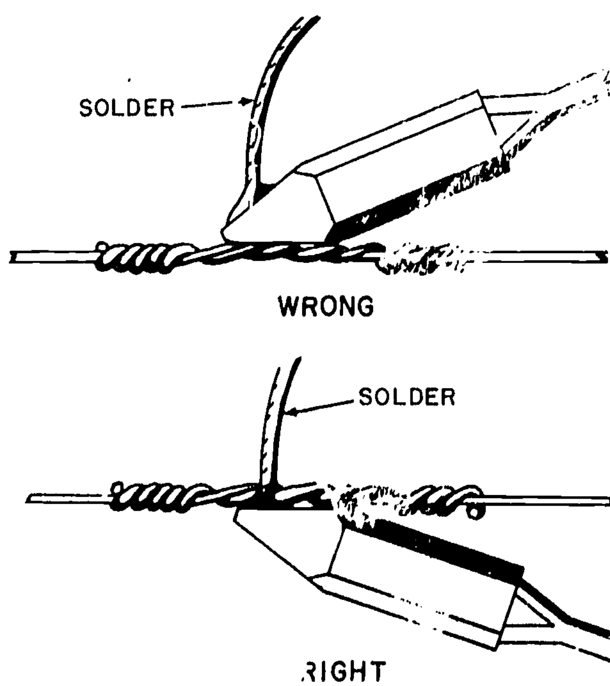
3. You can use either a soldering copper or a direct flame to sweat the solder to a splice. Small-sized wire is best soldered with a copper. Large-size requires a blowtorch or an alcohol torch.

Always remember in soldering that you will never get the solder to stick unless the splice itself is hot enough to melt the solder. To determine when the splice is hot enough, however, hold the solder to the side of the splice OPPOSITE the soldering copper. When the solder melts, the splice is hot enough, and the solder will then flow into every crack and hidden space. Figure 8-31 shows wrong and right ways of soldering a splice.

Refer to chapter 7, Basic Electricity, NAVPERS 10068-B and Tools and Their Uses, NAVPERS 10085-B for further information regarding soldering and splicing.

REPAIRS AND MAINTENANCE

Maintenance of buildings is necessary to prevent fire and electrical hazards caused by



73.261

Figure 8-31.—Right and wrong ways of soldering a splice.

defective wiring and equipment. The information below provides guidance for the maintenance of interior electrical systems of 600 volts or less. This includes such components as wiring, disconnecting devices, overcurrent protective devices, panelboards, feeders and illumination.

WIRING SYSTEMS

Loose wires, poor connections, bare conductors, defective convenience outlets and switches, defective attachment cords, and other unsafe conditions should be checked for and corrected when inspecting interior wiring. Rigid steel or aluminum conduit should be used in hazardous areas or where mechanical protection of wiring is necessary. The type of wiring provided should be in accordance with Navy specifications and the National Electrical Code.

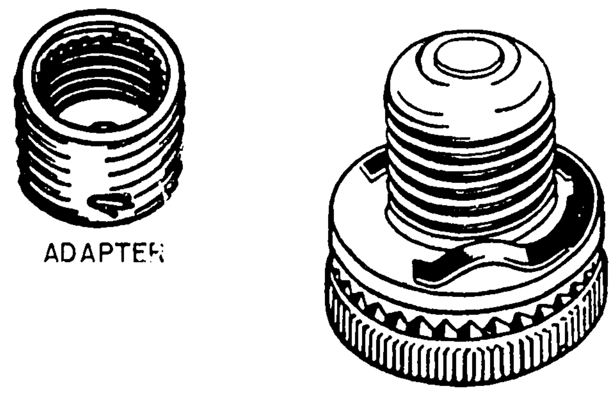
DISCONNECTING DEVICES

Panel connections made by bolts, screws or clamps should be tightened. Loose or poor connections are trouble sources and present a fire hazard. Properly made connections seldom loosen unless subjected to severe vibration.

Partially closed switches may result in burned contacts. Switches should be closed with one rapid motion so the blades are thrown completely into the clips or jaws of the switch. If the switch is tight or the contact is too stiff, monoxide grease on the blades will help close the switch.

FUSES

Fuses commonly found in interior wiring panels are plug fuses or cartridge fuses. Plug fuses are rated from 1 to 30 amperes. The base contact is the same size as a medium-size lamp. This type of fuze has a clear mica window to show the fuse link or some other means of indicating defective fuse link. A disadvantage of the ordinary plug fuse is that a penny or strip of metal may be placed in the fuse receptacle and held in place with a blown fuse to complete the circuit without giving fuse protection. One type of tamper-resisting base fuse uses an adapter that screws into the fuse receptacle and locks into place (fig. 8-32). The fuse, in turn, screws into the adapter. The adapter and fuse plug prevent using a 16 to 30 ampere plug fuse in a 0 to 15 ampere adapter, limiting the possibility of overfusing. Bridging a defective fuse is also practically impossible. Circuits supplying electric motors are subject to the momentary high current required for motor starting and which blows the ordinary fuse providing normal protection. Timelag fuses are used on these circuits. These fuses are available with regular screw bases or tamper-resisting screw bases. The internal construction of the timelag fuse is shown in figure 8-33. The heavy fuse link does not open quickly on motor starting currents. An overload heats the thermal control in the fuse link causing the solder to soften and release the spring at the end of the fuse link (fig. 8-33. view 1). Since motorstarting currents do not last long enough to melt the solder, the timelag fuse does not open. In case of a short circuit, however, the fuse link blows just as an ordinary fuse (fig. 8-33, view 2).



73.413
Figure 8-32. — Plug fuse with tamper-resisting base.

Two kinds of cartridge fuses, ferrule and knifeblade, are shown in figure 8-34. Knifeblade cartridge fuses with nonrenewable, renewable and timelag features are shown in

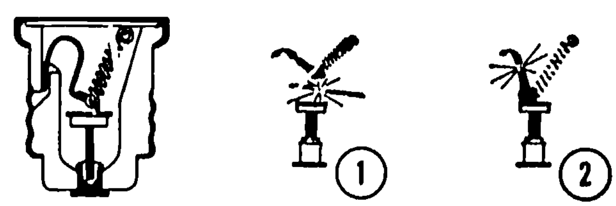


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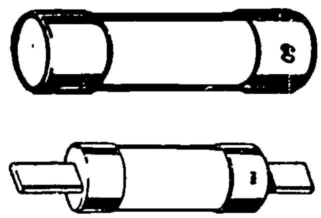
Figure 8-33. — Plug fuse with time lag.



73.415

Figure 8-34.—Cartridge fuses.

figure 8-35. The checklist below should be followed when installing or replacing cartridge fuses and blocks:

1. Check the fuse block to make sure the clips are making full contact with the fuse (fig. 8-36). Improper contacts cause fuses to overheat and may blow at less than rated current. Any prolonged overheating would destroy the fiber case and take the spring tension out of the clips.

2. Replace the clips that have lost their spring or use clip clamps (fig. 8-37).

3. If the inside of the clip is not bright and clean, brighten it with emery cloth.

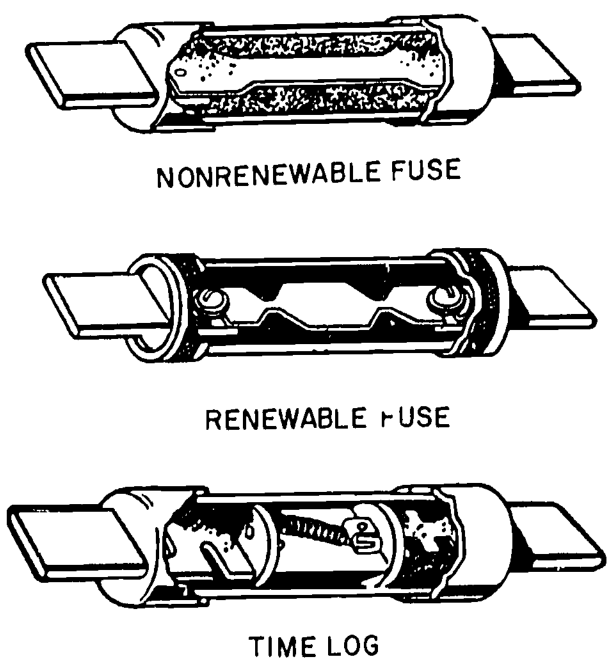


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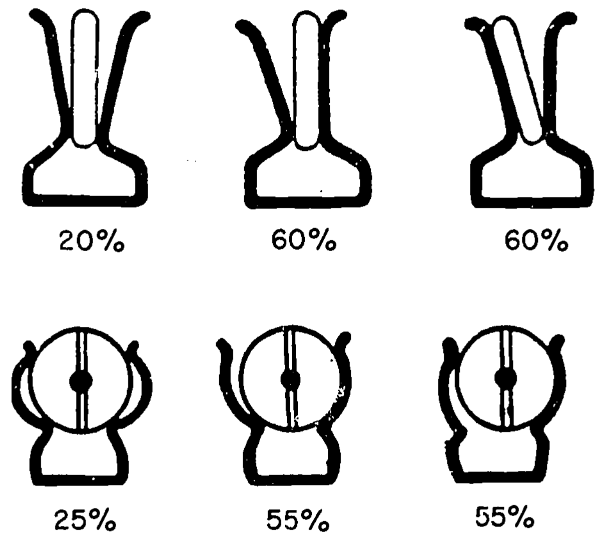
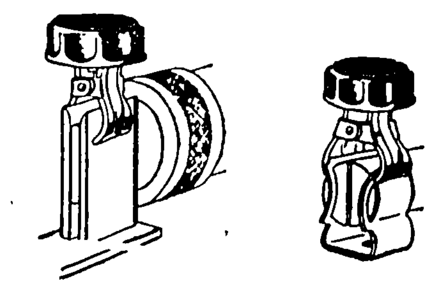
Figure 8-35.—Knifeblade cartridge fuses.



73.417

Figure 8-36.—Poor contact between clips and fuses.



73.418

Figure 8-37.—Clip clamps.

4. If the fuse does not require considerable pressure to insert it into the clips, insufficient contact pressure is present. Remove the fuse and draw clips together. If enough contact pressure is not obtained, replace the clips or use clip clamps.

5. To test for the degree of contact, insert the fuse in the clips and try to insert a thin strip of paper between the clips and the blade or ferrule. If paper can be inserted for a short distance, contact is insufficient and the condition must be corrected.

6. Poor contact at any point on the fuse block is just as bad as poor contact in the fuse or clips. Be sure the lugs are properly soldered

to wires or cables, that the bolts holding the lugs to the fuse block are drawn tight, and that the screws holding the clips to the fuse blocks are tight. Any excessive heating caused by poor contact is transmitted to the clips and fuse, destroying the spring tension of the clips and the fiber tube of the fuse.

7. Check the fuse blocks to make certain that the clips are straight and in line. If the fuse blades are twisted diagonally or bent out of line, the condition caused by damaged or misaligned clips has not been corrected.

A block having one straight and one bent clip is not improved by a fuse with one blade twisted diagonally. Contact in both clips is ruined because the twisted blade must be pushed over, causing both blades to be set into the clips at an angle.

A block with one clip out of line does not permit enough contact even though the blades may be bent out of line, because the angle of one blade is not in line with one of the clips. If the fuse is pushed into such clips, little contact is obtained, because the bent blade must be pushed over to get it into the clip, causing both blades to be set at an angle.

In replacing a blown fuse, keep in mind the following pointers:

1. Do not put in a new fuse until the source of trouble is located and corrected.

2. Do not replace a blown fuse with one of higher rating before determining the carrying capacity of the circuit. Using a fuse too large does not give adequate protection.

3. Do not insert fuses on a live circuit because the circuit may arc. Arcing causes a burr on the ferrule or terminal, which prevents good contact in the clips.

4. If the inside of the clip or contact of the fuse is not bright and clean, brighten it with emery cloth.

In case of a blown fuse, a check of the following conditions will aid you in locating the source of trouble:

1. Portions of the fuse making good contact will be clean and bright. When contact is poor, air gets into the contact surface and heating of the fuse causes oxidations, resulting in discoloration of surfaces. No matter how much a fuse is heated, little oxidation occurs if good contact exists.

2. When only one end of the fuse has a badly oxidized contact surface, poor contact positively existed at the end where the discoloration occurred. Oxidation of the bottom contact on a plug-type fuse indicates poor contact because the fuse was not screwed down tight.

3. If the washer or end ring on a ferrule-contact fuse is burned or partially melted, the cap was not screwed down tight.

4. Charred ends of the fiber tubes on nonrenewable or renewable fuses always indicate poor or inadequate contact (see fig. 8-38). The poor contact may be caused by abuse or lack of proper attention to fuse clips and fuse blocks. When only one end of the fuse is charred, poor contact existed at the charred end.

5. Charred ends of the fiber bar of a renewable fuse always indicate poor contact even though the fiber tube is not already charred. If poor contact is continued, the fiber tube is also sure to char.

6. Figure 8-39 illustrates fuse links blown under four different conditions. The first is a result of poor contact; the blow is between the reduced portion and the end of the link. The second is a normal blow when contact was good; the third is also normal, indicating a light overload. The fourth shows the result of heavy overload or short circuit.

7. Figure 8-40 shows blown links in nonrenewable fuses. When break occurs in center,

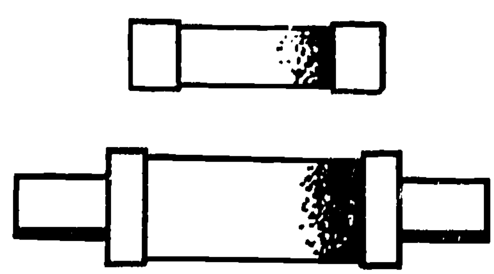


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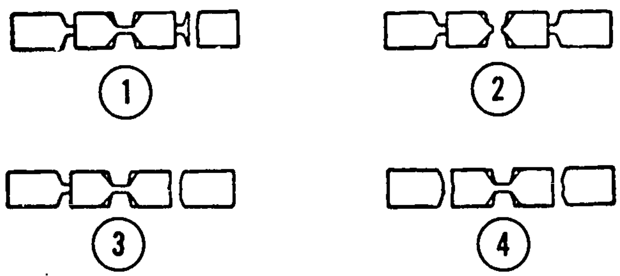
Figure 8-38. — Charred fiber tubes.



73.420
Figure 8-39.—Fuse links blown under various conditions.

73.421
Figure 8-40.—Blown links in nonrenewable fuses.

a good contact is indicated. Break at one end is usually caused by poor contact.

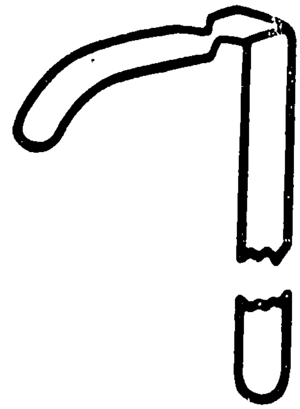
8. A plug-fuse link blown as shown in figure 8-41 indicates a poor contact and is usually accompanied by discoloration of the bottom contact. The blow should come at the center or upper portion of the link.

OVERLOADS

An overload occurs when the electric load becomes greater than the safe carrying capacity of the wiring or apparatus. It is usually indicated by frequent blowing of fuses or tripping of circuit breakers and abnormally hot wiring or equipment. When an overload appears likely, the load should be checked with an ammeter to determine the actual ampere load. An apparent overload may be caused by a partial ground on the circuit. Partial grounds should be located by ohmmeter or insulation resistance testing equipment. When an overload is found, part of the load should be transferred to another circuit or the wiring should be increased in size to provide adequate capacity.

LOAD BALANCE

An unbalanced load may result in heating of the wiring and panelboards and blown fuses or



73.422
Figure 8-41.—Blown link in plug fuse.

tripped breakers. An unbalance occurs when one side of a 3- or 4-wire circuit has a greater load than the other (fig. 8-42). This can be readily checked by using a clamp-on ammeter and taking ampere readings when the circuits are loaded. Unbalance can be corrected by changing part of the connected load from the overloaded side to the lightly loaded side. If this is not practical, part of the load may be transferred to another circuit, or a new circuit installed.

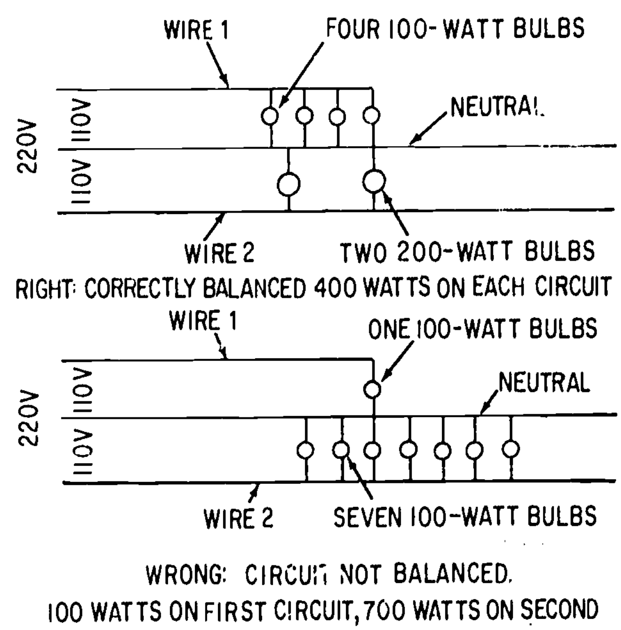


Figure 8-42.—Load balancing. 73.423

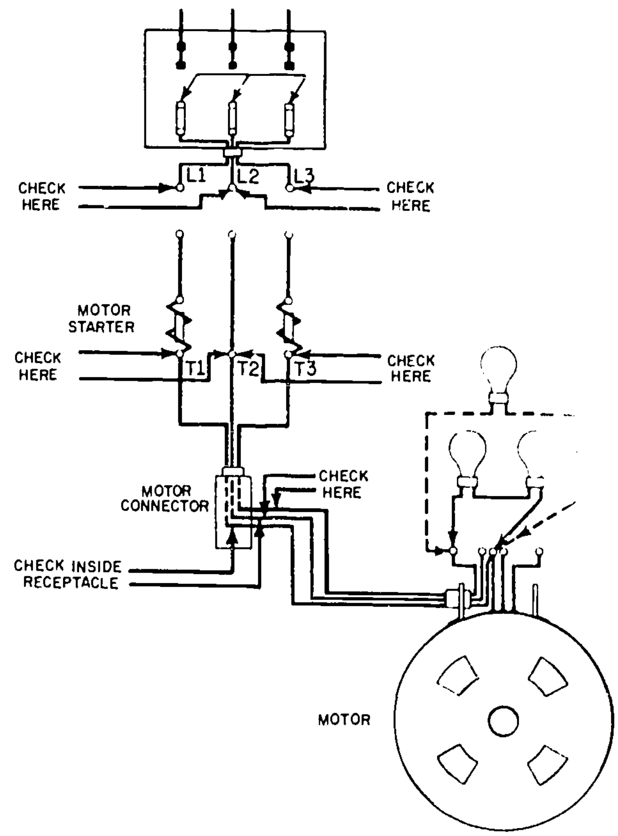
OPEN CIRCUITS

An open circuit exists when one or more conductors in a circuit are broken, burned open, or otherwise separated. Part or all of the lights will be out and the equipment will not operate even though the fuse has not blown nor the circuit breaker opened (see fig. 8-43).

When an open circuit occurs, check at the least energized outlet on the circuit for broken or loose connections. If a defective connection is found, repair and splice it out or install new wire as necessary.

If the trouble is not visible, use a test lamp to trace the circuit back to the source (fig. 8-44).

NOTE: For 110-volt motors, use a single bulb rated from 110 to 130 volts. For 220-volt motors, use one 220-volt bulb or two 110- to 130-volt bulbs in series.



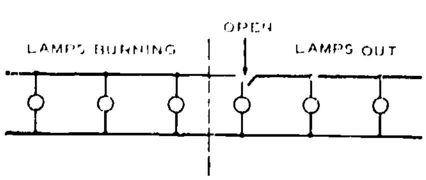
73.425
Figure 8-44.—Using a test lamp at various points in a motor circuit to locate a line break.

SHORT CIRCUIT OR GROUND

A short circuit results when two bare conductors of different potential come in contact with each other. If a hot conductor is making contact with some metallic part of the wiring system, such as the conduit (fig. 8-45) or a motor frame connected to ground, it is called a ground. A high resistance ground may cause current flow without opening a breaker or blowing a fuse.

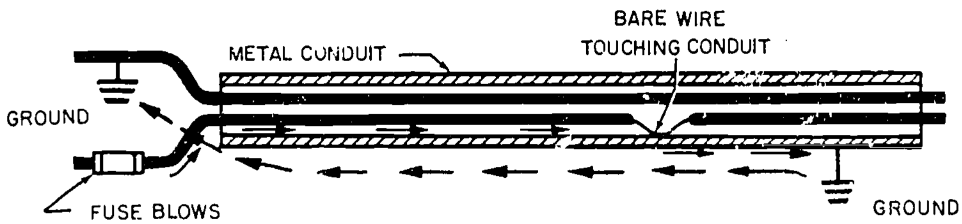
To determine the cause and location of trouble in a building wiring circuit, protected by plug fuses, the following procedure is suggested:

Make sure the circuit is not overloaded. Then remove the blown fuse and screw a 200-watt lamp into the fuse receptacle. If the lamp burns at full brilliancy with the neutral open, the circuit is grounded. If the lamp burns with the neutral closed and goes out when the neutral is opened, a short circuit is indicated.



73.424
Figure 8-43.—Open circuit with part of lights out.

If a short circuit exists, leave the 200-watt lamp in the fuse receptacle to prevent the flow of excessive current. If the trouble is not discovered by a quick visual inspection, pull out the plugs of all portable equipment on the circuit and turn off all wall switches. If the short circuit is cleared during this isolation process, the lamp in the fuse receptacle will go out or glow dimly. Do not leave the 200-watt lamp in the receptacle after insulating the defective device. Leaving the lamp in the receptacle will create a low voltage condition. If certain loads—for example, motors—are connected, they could be seriously damaged by the low voltage.



73.426

Figure 8-45.—Wire grounded by conduit.

If the 200-watt lamp in the fuse receptacle continues to burn after all the load is disconnected, install a test lamp in the nearest convenience outlet on the circuit. Open the circuit at various outlet points and observe the lamp. When the faulty section of the circuit is disconnected, the test lamp will burn dimly.

LIGHTING SYSTEMS

Each lighting installation is designed to produce a specific level of illumination adequate for those working in the area. The amount of illumination initially provided starts to decline almost as soon as it is put in operation. This reduction is caused by dirt on the lamps and luminaires, a decrease in lamp lumen output, and dirt on the room walls and ceilings. Illumination should be sufficient to eliminate eyestrain, maintain a high level of production, and promote safety and employee morale.

Incandescent Lamps

Lighting fixtures are designed for a particular lamp size and type. Many fixtures, however, were installed in military buildings long before the manufacturers started producing higher and higher wattage lamps in ever smaller envelopes. Consequently, it is possible to use much higher wattage lamps than the fixture or the circuit can handle adequately. Excessive heat of higher wattage lamps can damage the sockets, increase failure rate, and overload the circuits. Personnel are cautioned to use only the lamp size (in watts) recommended for the fixture rather than a higher wattage lamp that may physically fit.

Incandescent lamps come in a variety of voltage ratings. For most applications, the lamp voltage rating nearest the available line voltage should be selected. Under this condition, the lamp will produce its rated values of life, watts, and light output. Many incandescent lamps are available with life ratings considerably in excess of ordinary general service lamps. Some have ratings of 5,000 hours or more and some even are guaranteed to burn for 5 years. Use of these lamps is not recommended because the initial cost is comparatively high and the extended life is gained by reducing the light output. There are, however, a few areas where it is necessary to use bulbs with a long life. Typical locations include high ceiling auditoriums, exit lights, stairwells, and marker lights on towers or fire alarm boxes. For these areas, do not use a special rated lamp. Do use an ordinary general service lamp whose voltage rating is higher than the circuit voltage, e.g., 130-volt or higher lamps for 120-volt circuits. By operating the lamp below its rated voltage, the life is increased at a sacrifice in light output. For general use, the lamp voltage rating nearest the available line voltage should be used.

There are many kinds of incandescent lamps especially designed for placement in variety of situations; for example, under severe physical conditions (such as vibration or extreme temperatures), in inaccessible locations or when special lighting effects are desired. Some of these types of incandescent lamps and their uses are:

INSIDE-FROSTED LAMPS are used in most fixtures designed for incandescent lamps. The frosted finish reduces lamp brightness and glare.

CLEAR LAMPS are used in fixtures where control of the light is required (such as in reflectors having polished reflecting surfaces and in enclosed globes or reflectors of prismatic glass), particular where concentrated light control is required, as in high narrow bays.

Reflector equipment of the diffusing globe type, where the lamp protrudes through the bottom of the fixture, requires WHITE BOWL LAMPS. The white bowl reduces the surface brightness and glare from the working surfaces.

SILVERED-BOWL LAMPS are used principally for indirect lighting and in reflector equipment. The fixture parts should not touch the lamp as the thermal expansion may cause the bulb to crack and fail prematurely.

REFLECTOR LAMPS, with the reflecting surface inside the lamp are, in effect, a fixture in themselves. The lamps can lose their effectiveness due to the collection of dust and dirt on the exterior.

PROJECTOR LAMPS are installed in indoor and outdoor display lighting fixtures. They employ a self-contained reflector but have advantage over the reflector type since they are suitable for extreme temperature conditions and provide more accurate light control.

HEAT AND DRYING LAMPS, available with built-in reflectors or with separate reflectors, are an inexpensive answer to a requirement for instantaneous infrared energy. The reflector bulb keeps the initial cost to a minimum and provides a new reflecting surface with each new lamp.

HARD-GLASS LAMPS, made of special glass with high resistance to thermal shock, are effective where rain, splashing liquids, insects, snow, fixture parts, or hot metallic spray may touch the glass bulbs.

VIBRATION SERVICE LAMPS are available that withstand excessive vibration which cannot be eliminated by flexible fixture mounting.

Where the lamp will be subjected to shock, such as the end of a drop cord or near machinery you will want to select ROUGH SERVICE LAMPS. With filament supports, these lamps can withstand severe shocks without failure.

High-cost replacement areas such as towers, industrial high bays, theater marquees, halls, and stairwells are lighted with LONG-LIFE LAMPS.

QUARTZ-IODINE LAMPS offer a very concentrated sou[illegible] of incandescent light with excellent light control characteristics, good color, and a life twice that of regular general service incandescent lamps. They depreciate at a lower rate than the general service lamp. The lamp cost is considerably higher, however, than a general service lamp, and a special fixture is required.

Fluorescent Lamps

There are two principal types of fluorescent lamps, instant-start and rapid-start preheat lamps. Both have practically the same physical dimensions but different internal construction. The type of circuit in which the lamp should be used is etched on the end of the lamp. The rapid-start preheat lamp operates satisfactorily with either the preheat or rapid-start circuits. It has a very short lamp life in an instant-start circuit. The instant-start lamp operates satisfactorily with an instant-start ballast, burns out the ballast in a rapid-start circuit, and does not light in a preheat circuit. Preheat lamps dominated the field for many years but are no longer considered a major type. They continue to be in use, however, particularly in fixtures using lamps smaller than 40 watts. A typical preheat circuit is shown in figure 8-46. Other examples of circuits for the major types are readily found in current manufacturers' publications. An example of some circuits is shown in figure 8-47. The 4-foot rapid-start lamp is the preferred lamp for most applications.

Fluorescent lamps are available in a variety of colors for decorative use as well as numerous shades of white for general illumination. The predominant white shade recommended for most office areas is Cool White. Other shades of white used for various purposes include Daylight, Deluxe Cool White, White, Warm White, and Deluxe Warm White. Daylight and Cool White provide a crisp, cool, business-like atmosphere and the warm whites find application in restaurants, homes, theaters, and similar areas. Colored materials will appear more favorable under a fluorescent light that contains a high component of the same color. Blue backgrounds improve with the cool whites and daylight. Deluxe warm whites flatter reds while white and warm whites strengthen oranges and yellows.

Fluorescent lamps require ballasts to limit the current and to supply proper voltage to start and to operate the lamps. For general lighting purposes, the ballasts also contain a

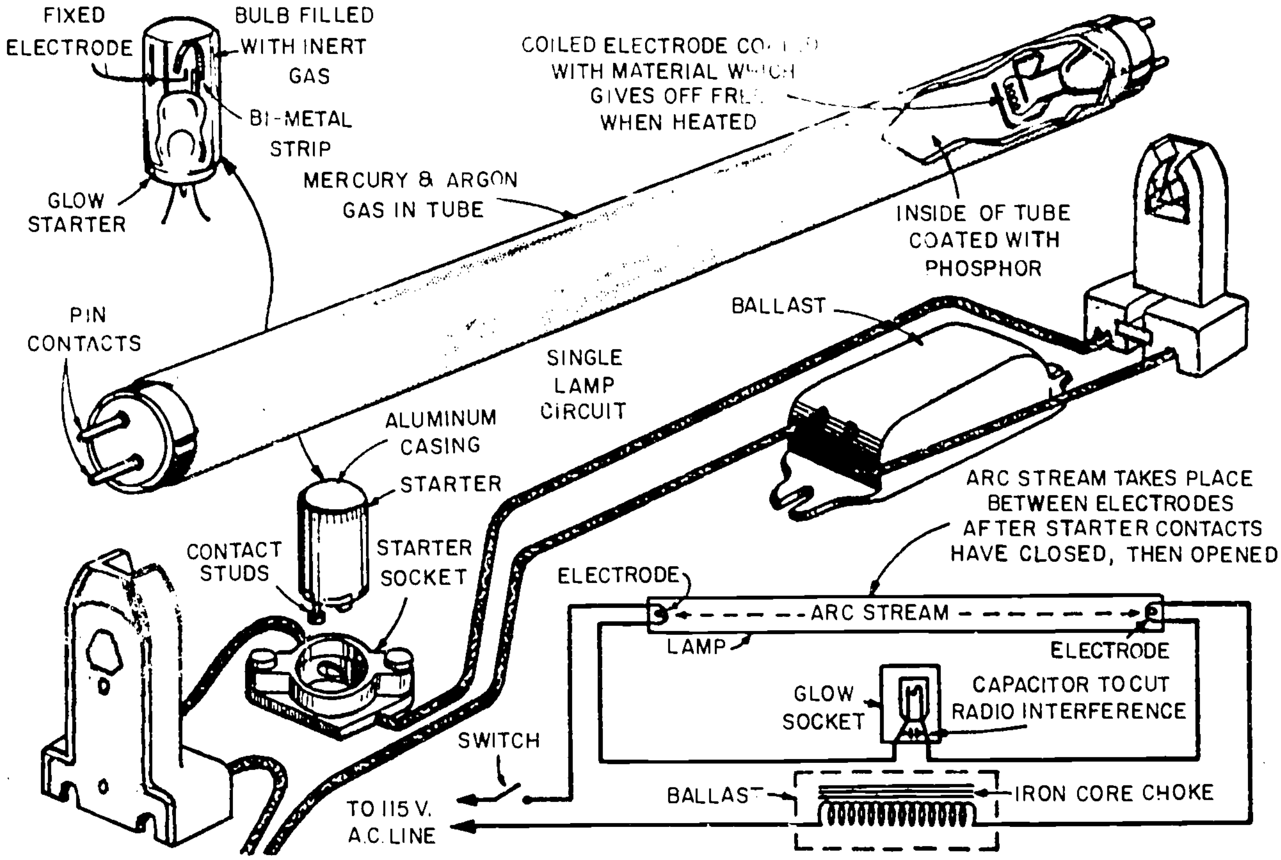


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Figure 8-46. — Preheat fluorescent lamp and circuit.

capacitor to improve power factor. The current National Electrical Code requires that all indoor fluorescent fixtures (except those with simple reactance ballasts) must incorporate ballasts with thermal protection. The thermal protector isolates the ballast (and fixture) from the circuit in the event of overheating. As a result, damage from fires and from leaking compounds should be reduced. There are small fuses available that can be installed in the fixture to provide this protection for existing ballasts.

Mercury Lamps

Mercury lamps (fig. 8-48) have the best maintained light output because the electrodes operate at a relatively cool temperature resulting in less evaporation of the metals and oxides. The clear mercury lamp has a better lumen maintenance than those with phosphor coating. Long average life (16,000 hours and up) is a primary characteristic of most mercury lamps. There will be a different economic life for mercury lamps at each installation depending on lamp mortality, power cost, equipment and wiring costs, frequency of replacement and cleaning of lamps, and other factors. Mercury lighting is one of the most economical means of lighting high- and medium-bay industrial areas, particularly in areas where color rendition is not critical. Small wattage lamps have been introduced, and it is anticipated that future designs will see a more widespread use of these in low-ceiling nonindustrial areas. While the lamp bases are the same size as incandescent lamps, mercury lamps must never be used to replace a burned-out incandescent lamp because a ballast must be used with mercury lamps. An objectionable characteristic of mercury lamps is the time required to reignite (several minutes) after a momentary loss of power.

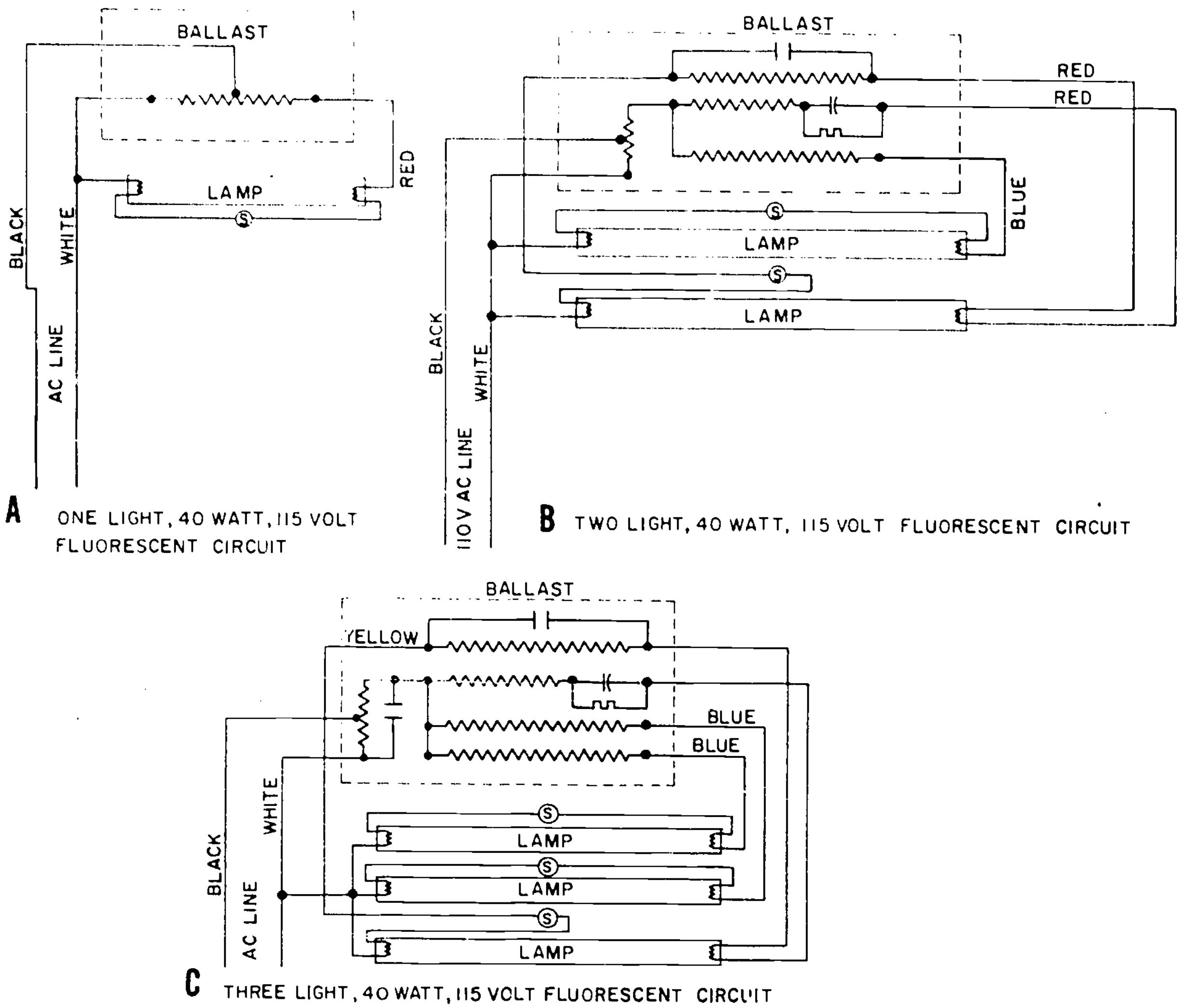

Figure 8-47.—Representative fluorescent circuits. 73.35

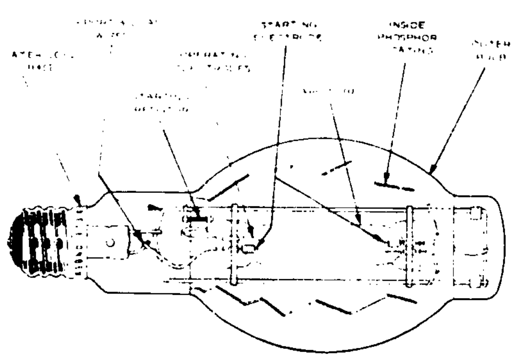

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Figure 8-48.—Mercury lamp.

Metallic-Vapor Lamps

Metallic-vapor lamps resemble mercury-vapor lamps in appearance and have similar uses. The initial efficiency and control are better with metallic-vapor lamps than with mercury-vapor lamps. In regard to disadvantages, the rate of depreciation is much greater with metallic than with mercury, the cost is higher, and the life expectancy is shorter.

High-pressure sodium-vapor lamps are used for highway interchanges, parking lots, and high-bay industrial areas. They are the most efficient of the light sources in general use in number of lumens produced per watt of electricity.. The relative cost is high, the life ratings are not well established, and a special ballast is required. The color is slightly yellowish.

Overall Illumination

Walls, ceilings, and surroundings are an important part of the overall illumination system since they redirect light to the working area. The most efficient lighting system is obtained when the fixtures are new and when the walls, ceilings, floors, and furnishings of the room are colored with a high reflectance color. Lighting is, however, only one of many factors that make up the whole environment. While the highest lighting efficiency may be maintained in a completely white room, the psychological effect of such surroundings on the occupants may be less than harmonious. The use of color in the surroundings, even if it means sacrificing lighting efficiency, is necessary for the well-being of the occupants. Ceilings should have the lightest color, preferably an off-white. Shiny surfaces should be avoided as they result in glare. As mentioned earlier, lighting levels start dropping immediately after the installation of the fixtures. Lamp burnouts and lamp depreciation contribute to this but the principal cause is the accumulation of dirt. It is not uncommon to find lighting levels 1/2 the initial values after only a year or so of operation. The lighting maintenance program must include cleaning and painting of the walls and ceilings in addition to the fixture cleaning schedule.

TROUBLESHOOTING LAMPS

as light sources are designed to operate most efficiently and economically at their rated voltages, special emphasis should be given to using lamps to suit the voltage of the circuit. Operation within the normal operating range is desirable, because both overvoltage and undervoltage operations have a determined effect on the life, efficiency, and economy of the light source. The effect on lamps operated over or under their rated voltage range is as follows:

FLUORESCENT LAMPS. Line voltage higher than the maximum of the ballast range will shorten lamp and ballast life. Line voltage below the minimum range will reduce illumination and may cause uncertain starting of fluorescent types.

INCANDESCENT LAMPS. Line voltage higher than the maximum lamp range will increase the light output but will shorten lamp life. Line voltage below the minimum range will extend lamp life but will reduce light output approximately 3 percent for each 1 percent in voltage drop.

MERCURY LAMPS. Line voltage higher than the maximum lamp range will shorten lamp and ballast life. Line voltage below the minimum range will reduce illumination and may cause uncertain starting.

LAMP GUIDES. The most common troubles encountered with lamp equipment, the probable causes, and the suggested solutions are contained in table 8-2.

MAINTENANCE

Lighting has a great influence on the quality and quantity of work as well as a direct bearing on employee morale. The necessity for periodic attention to the lighting system cannot be overemphasized. To prevent progressive deterioration of the system, regular maintenance and prompt repair of any deficiency are essential.

Maintain the required illumination intensity by keeping lamps, fixtures, and reflective areas clean and in good repair; replacing defective lamps; and keeping the voltage steady.

It is well-known that dirt absorbs and masks light. The progressive decrease of light caused by accumulating dirt renders periodic cleaning of lighting equipment a necessity. The frequency of cleaning depends largely upon local conditions. Fixtures in air-conditioned and air-filtered rooms may require cleaning only once a year. In an atmosphere which is heavy with dust and fumes, cleaning every few weeks may be necessary.

The cleaning schedule for a particular installation should be determined by light meter readings after the initial cleaning. When subsequent foot-candle readings have dropped 20 to 25 percent, the fixtures should be cleaned again. Readings should be made with the light meter at the working surface with the meter reader in the position of the operator or person using the working surface.

Table 8-2. — Lighting maintenance chart

INCANDESCENT

SYMPTOM	POSSIBLE CAUSE	REMEDY
LAMP OUT, BUT NOT DEFECTIVE.	LOOSE LAMP, OR LOOSE OR BROKEN CONNECTIONS	TIGHTEN IN SOCKET, OR SECURE TERMINALS, OR REPAIR WIRING.
LAMP BURNS DIM	LOW VOLTAGE	MATCH LAMP RATING TO LINE VOLTAGE INCREASE LINE VOLTAGE.
SHORT LAMP LIFE	HIGH VOLTAGE, OR BULB CRACKED, OR INCORRECT LAMP, OR EXCESSIVE VIBRATION.	MATCH LAMP RATING TO LINE VOLTAGE AND REDUCE VOLTAGE. REPLACE LAMP. REPLACE WITH LAMP OF PROPER RATING. USE SHOCK-ABSORBING DEVICE.
LAMP BREAKAGE	WATER CONTACTS LAMP BULB, OR BULB TOUCHES LUMINAIRE.	USE INCLOSED, VAPORTIGHT LUMINAIRE IF WATER VAPOR IS PRESENT. SEAL JOINT WHERE CONDUIT STEM ENTERS LUMINAIRE. USE CORRECT-SIZE LAMP. STRAIGHTEN SOCKET.

FLUORESCENT

SYMPTOM	POSSIBLE CAUSE	REMEDY
LAMP DOES NOT START OR FLASHES ON AND OFF NOTE: A FLASHING LAMP USUALLY INDICATES END OF LAMP LIFE.	LAMP PINS NOT CONTACTING, OR LAMP WORN OUT, OR STARTER DEFECTIVE, OR LOW LINE VOLTAGE, OR FAULT IN CIRCUIT OF LUMINAIRE	SEAT LAMP FIRMLY AND CORRECTLY. REPLACE WITH TESTED LAMP. REPLACE WITH TESTED STARTER. CHECK WITH VOLTMETER. CHECK WIRING AND LAMP HOLDERS. CHECK BALLAST.
LAMP FLICKERS, ARC WIGGLES, SWIRLS OR FLUTTERS	DEFECT WHICH OCCURS IN BOTH NEW AND OLD LAMPS	TURN LUMINAIRE ON AND OFF SEVERAL TIMES. ALLOW A NEW LAMP TO OPERATE A FEW HOURS FOR SEASONING. REMOVE LAMP AND SHAKE ONE END DOWN. REPLACE LAMP IF FLICKER PERSISTS. IF FLICKER IS REPEATED IN NEW LAMP, REPLACE STARTER.
LAMP STARTS SLOWLY *(should start in a few seconds)*	LOW LINE VOLTAGE OR SLOW STARTER	CHECK WITH VOLTMETER. REPLACE STARTER.
SHORT LAMP LIFE *(A few early failures do not indicate average for group. Some fail after a few hundred hours, others last 1000 - 6000 hours.)*	LOW LINE VOLTAGE, OR LAMPS TURNED ON AND OFF TOO OFTEN.	CHECK WITH VOLTMETER.
RADIO INTERFERENCE	MAY ORIGINATE FROM OTHER SOURCE -RADIO TOO CLOSE TO LAMP-AERIAL LEAD-IN NOT SHIELDED.	OPERATE RADIO WITH FLUORESCENT LAMPS TURNED OFF. MOVE RADIO 9 TO 10 FEET FROM LAMP. SHIELD LEAD-IN AND GROUND SHIELD. INSTALL FILTER RADIO OR LUMINAIRE.
NOISE FROM BALLAST. *(Don't expect perfect silence)*		IF QUIET NECESSARY, TAKE SPECIAL PRECAUTIONS IN LOCATING BALLAST. IF UNIT VERY NOISY, REPLACE BALLAST.

MERCURY LAMP

SYMPTOM	PROBABLE CAUSE	REMEDY
LAMP FAILS TO START	LAMP LOOSE.	TIGHTEN IN SOCKET.
	LAMP BURNED OUT.	REPLACE.
	LOW VOLTAGE.	INCREASE LAMP VOLTAGE BY CHANGING TRANSFORMER TAP.
	WIRING FAULT.	CHECK WIRING. TIGHTEN CONNECTIONS
	LOW TEMPERATURE.	LAMPS MAY NOT START WHEN TEMPERATURE IS BELOW 32° F.
	FLUCTUATING VOLTAGE.	CHECK LINE VOLTAGE. *(Momentary dips of 10 percent, or more, often cause light to go out.)*
LAMP FREQUENCY GOES OUT	WIRING FAULT.	TIGHTEN CONNECTIONS. CHECK WIRING. SEPARATE LIGHTING CIRCUITS FROM HEAVY POWER CIRCUITS.
ANNOYING STROBOSCOPIC EFFECT	CYCLIC FLICKER.	WHERE THERE IS A 3-PHASE SUPPLY, CONNECT LUMINAIRES ON ALTERNATE PHASES. ON SINGLE-PHASE, ADD INCANDESCENT LUMINAIRES TO THE SYSTEM.

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Lighting equipment should be washed, not just wiped off with a dry cloth. Washing reclaims 5 to 10 percent more light than dry wiping and reduces the possibility of marring or scratching the reflecting surface of the fixtures.

To clean removable glassware, reflectors, and diffusing louvers, immerse in a solution of synthetic detergent cleaner and scrub with a soft brush or sponge. When incrustation is not removed by scrubbing, use No. 0 steel wool to remove dirt film. Rinse in warm clear water and dry with a clean cloth.

CAUTION: Do not immerse lamp base or electrical connections in the cleaning solution.

Glassware, reflectors, and diffusing louvers that cannot be removed should be cleaned as follows:

Wipe with a moist cloth or sponge, using a solution of synthetic detergent cleaner. When incrustation is not removed by sponging, use No. 0 steel wool to remove dirt film. Care should be taken to ensure that shreds of steel wool do not touch the pin contacts or get into the lamp socket. Wipe off excess moisture with a clean cloth. Clean fixture holders and stem hangers with a moist sponge or cloth dampened with synthetic detergent cleaner and wipe dry. Enameled, chrome, aluminum, or silver-plated reflecting surfaces that cannot be adequately cleaned and polished should be replaced.

Neglected lamp outages reduce illumination. If burned-out lamps are not promptly replaced, illumination may drop to unsafe foot-candle levels in a short time, due to outages alone. In some cases it may be satisfactory and more economical to clean lamp surfaces and fixture interiors only at the time of relamping. Each activity must determine whether cleaning is to be accomplished by electrical, self-help, or custodial service personnel.

Burned-out lamps are replaced on request. To prevent reduced illumination from lamp outages:

1. Instruct employees to report burnouts as they occur.

2. Replace blackened or discolored lamps even though they are still burning. Discoloration indicates the lamp is nearing the end of its useful life.

3. Replace fluorescent lamps as soon as they begin to flicker. A burned-out lamp in a live circuit may cause damage to starter and ballast. Blackening at the ends of the tube adjacent to the base indicates that the lamp is near the end of its useful life.

4. In general, replace with the same type, wattage, and voltage as that of the lamp removed. If frequent burnouts occur, voltage rating of lamps may be too low. Lamps of higher wattage than called for on lighting design plans should not be used.

CHAPTER 9

CENTRAL POWER STATIONS

Since the days of Faraday, electricity has been generated at various power sources. Waterfalls, coal, and oil have been used as sources for the conversion of their energy into electricity.

At present, hydroelectric, steam-turbine, or internal combustion engine generators at central power stations generate electricity economically and efficiently because of their physical proximity to their sources of power or customers.

Steam turbine generators are utilized on larger Navy shore installations where the prime purpose of the steam is for heating, or aboard steam-driven ships.

Large diesel engines are the kind most of you will encounter other than the portable sets discussed in this chapter. Maintenance and repair of the internal combustion type are relatively easy compared to the hydroelectric and steam turbine generators.

Today nuclear power is looming as a source of electricity. As time goes on, more and more of the electrical energy supplied in the United States will originate from nuclear power.

Especially selected CEs are sent to nuclear reactor schools for special training in nuclear power generation. CEs operate these plants in certain shore installations for the Navy. Thorough knowledge of electrical theory and practical ability are prerequisites for selection for training in the nuclear power field. Study this book and other training material thoroughly if you want to be considered for such training.

As a Construction Electrician you will help in the installation, operation, maintenance, and repair of advanced-base generating equipment. This equipment is portable and ranges in size from 1.5 kw to 600 kw. In time of war or national emergency, portable generator equipment will normally be used at temporary overseas bases. Even in peacetime, portable equipment may be used at remote bases.

Table 9-1.—Family of Engine-Generators

	ALTERNATING CURRENT					
FREQUENCY	60-HERTZ					
VOLTAGE	120		120/208		120/208 240/416	
PHASE	1		1 & 3		3	
WIRES	2		4*		4	
FUEL	G	D	G	D	G	D
KW RATING						
1.5	X					
3			X			
5			X			
10			X			
15					X†	X†
30					X†	X†
45						X†
60					X	X†
75						X†
100						X†
150						X†

G-GASOLINE DRIVEN. D-DIESEL DRIVEN.

† -THESE GENERATORS TO PRODUCE EITHER 50- OR 60-HERTZ.

* -PANEL CONNECTIONS PERMIT, AT RATED KW OUTPUT: 120/208V 3-PHASE 4-WIRE, 120V 3-PHASE 3-WIRE, 120V SINGLE PHASE 2-WIRE, 120/240V SINGLE PHASE 3-WIRE.

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At large, more permanent activities overseas, you may have duties associated with the installation of large electrical power systems.

Generating equipment installed at advanced bases is simple, rugged, and reliable. It is also flexible in that power can be supplied even after part of the plant is damaged. It is up to you to take advantage of these characteristics by learning how to install, operate, maintain, and repair the components of this electric plant and its distribution system.

You can learn how by applying the fundamentals of electricity and electronics and by observing a few simple rules and working practices.

GENERATOR EQUIPMENT

When an overseas base is first established, electric power is needed in a hurry; you will not have time to set up a centrally located generating station. Instead, you will spot a portable plant at each important location requiring power. Table 9-1 lists some of the standard alternating current generators available. These standard generators are capable of meeting the power requirements of advanced bases.

DIESEL AND GASOLINE ENGINE SETS

Both gasoline and diesel engines are useful as prime movers for generators. Diesel engines are used to drive the larger generators (15 kw and higher) because, they are highly reliable in operation, have a low fuel consumption per horsepower per hour, reduced fire hazard, lower maintenance cost and longer useful life than the gasoline engine. Gasoline engines are more suitable to supply power and light on an intermittent or emergency basis. Their initial cost is

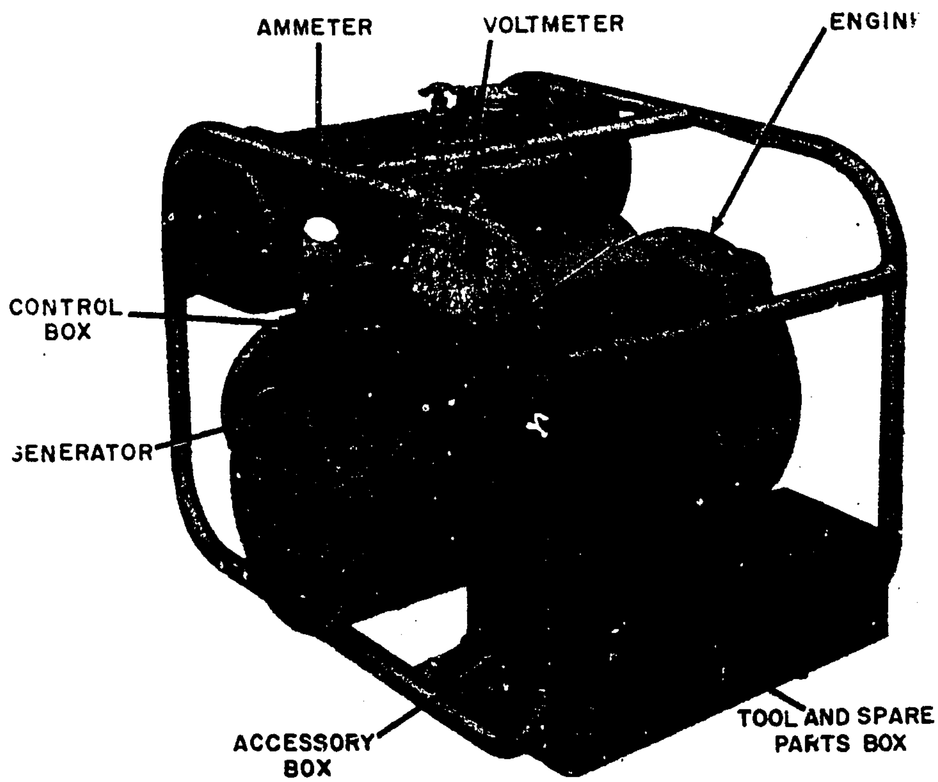

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Figure 9-1.--Gasoline engine generator.

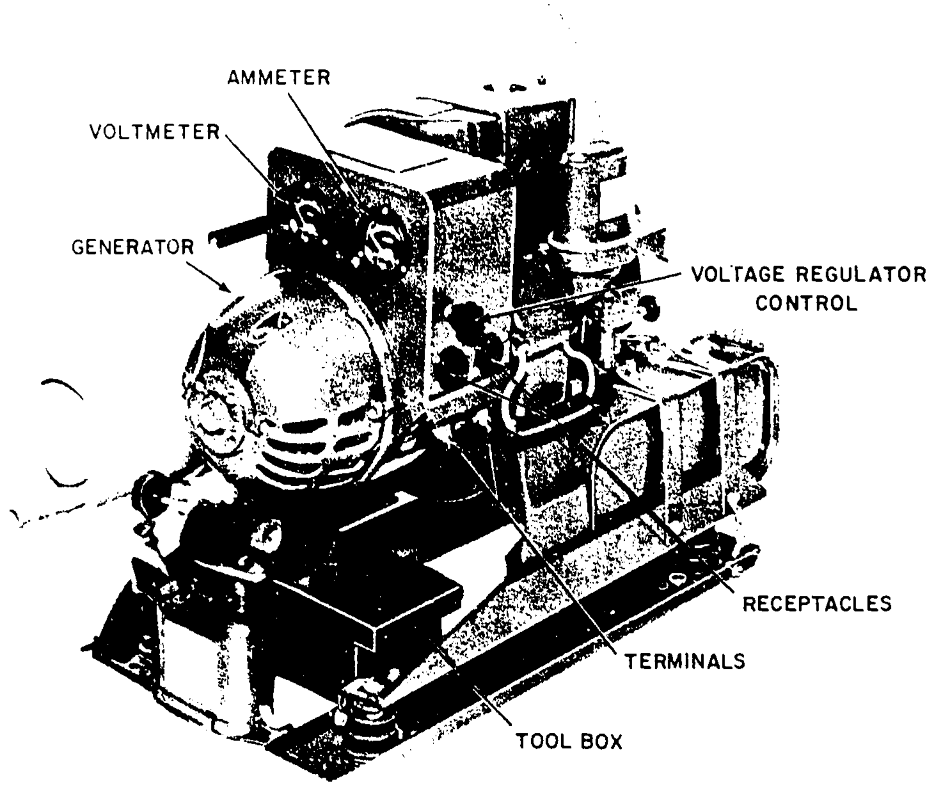

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Figure 9-2.—Representative 1.5-kw., 120-volt, 60-hertz, portable generator set.

much less than that of diesel engines, but maintenance costs are higher and their useful life is short.

The one cylinder engine driven generator in figure 9-1 is about the simplest you'll find in an advanced base. It will handle loads up to 1.5 kilowatts. A starting rope wrapped around the flywheel is used to start the engine in the same manner as that for small outboard or power lawn motors.

Some gasoline-driven generators used by the Seabees supply as much as 10 kilowatts of a-c power. These may be used as emergency standbys for a small central power station. They are skid-mounted, and if equipped with weatherproof metal housing, are designed primarily as portable sets for outdoor operation.

GENERATORS

The 1.5-kw output generator delivers 120 volts single-phase at a frequency of 60 hertz. It is a very versatile and widely used small generator because its output is adequate for the communications and lighting requirements for use in the field. Figure 9-2 shows a 1.5-kw generator mounted on a base with handles to make it transportable by two men. The simplicity of operation is evidenced by a single control consisting of a field rheostat or voltage-regulator control to permit adjustment of the voltage output. Representative 10- and 60-kw generators are illustrated in figures 9-3 and 9-4.

The electrical loads to be supplied, power, voltage, phase, frequency and duty cycle requirements govern the selection of generating equipment. Probable load deviation, probable life of the installation, availability of fuels, and availability of skilled personnel are other important factors.

Electrical plants at advanced bases serve a varied load of lighting, heating, and power equipment, most of which demand power day and night. The annual load factor (the ratio of average power to peak power) of a well-operated active base should be 50 percent or more with a power factor (explained later in the chapter) of 80 percent or higher. If the load is more than a few hundred feet from the power source, a high voltage distribution system is required.

If several generators are to serve primary distribution systems, they should generate the same voltage to avoid need for voltage transformation. The number of phases required by the load may differ from that of the generator. As loads can usually be divided and balanced between phases, most generators of appreciable size are wound for three-phase operation.

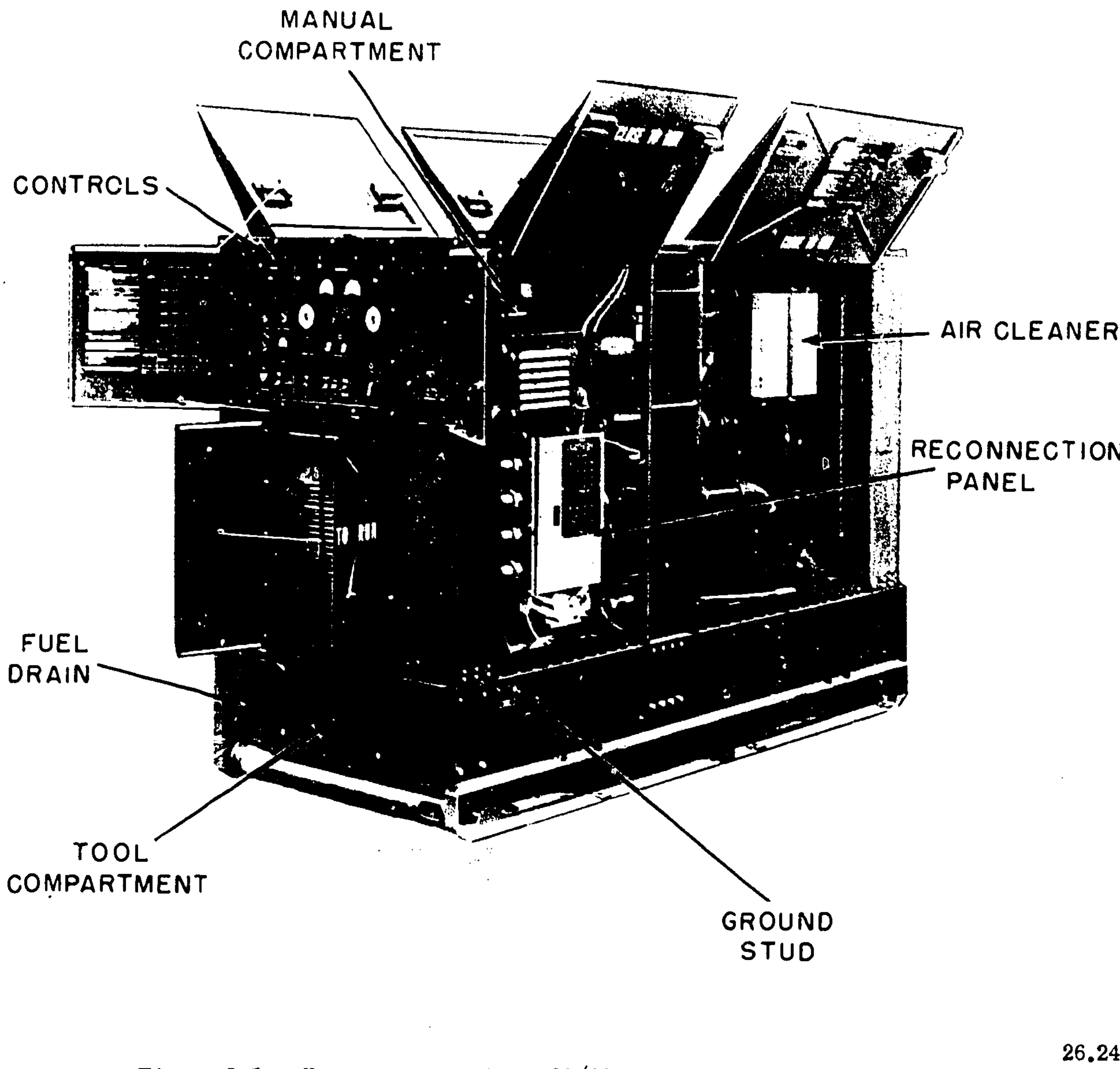

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Figure 9-3.—Representative 120/208-volt, three-phase, 4-wire, 60-hertz, portable generator set.

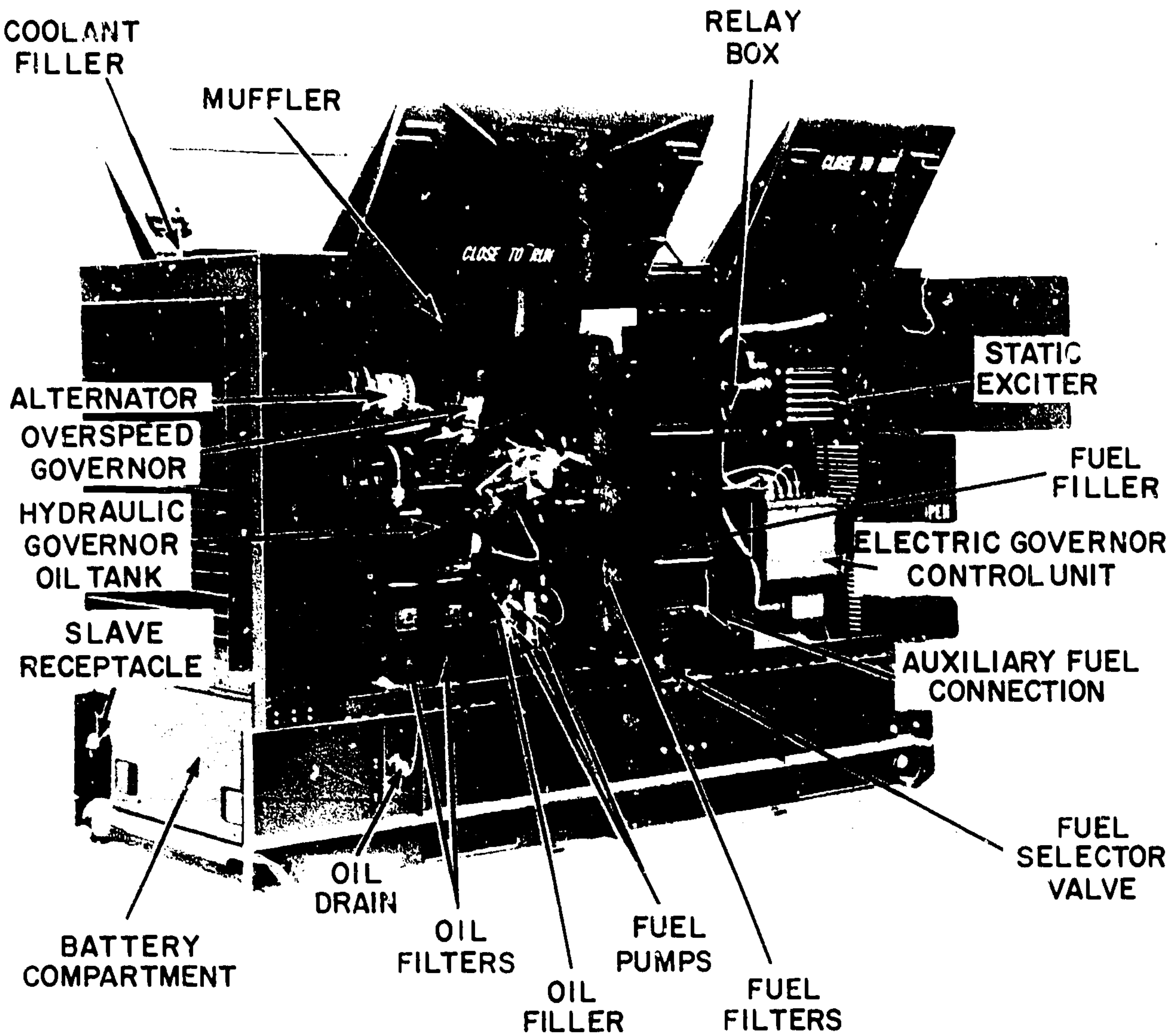

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Figure 9-4.—Generator set, left front, three quarter view.

CONTROL PANELS

A generator must be set up immediately when an advanced base is first occupied, to provide power for temporary lighting, communications, and other services as needed. If the base is to be a permanent one, a central power station must be established for control and distribution of electric power to all spaces and services which are to be located at the base.

Every generator set at an advanced base must have a control panel which may or may not be a built-in part of the unit. The size of the panel and the number and type of controls mounted thereon will depend on the size of the generator unit and the type of equipment for which the station must supply power.

For an initial, temporary unit the panel or control board contains all the necessary meters, switches, and other devices. For a permanent central power station with two main generators, the control panel is a combination of two boards, one for each main generator unit. This assembly is known as "switchgear."

Figure 9-5 shows the control panel for a portable single-generator unit. Figure 9-6 shows the control board of a single generator in a central power station. Figure 9-7 shows the switchgear unit for a central power station containing two diesel-electric plants.

The functions of the controls identified in figure 9-5 are given below.

The STARTER SWITCH controls the starting motor. Pushing the starter switch completes the circuit between the battery and the starting motor.

The THROTTLE normally controls the amount of fuel fed into the cylinders of the engine and therefore controls the speed of the engine. Most of the advanced base generating units are equipped with a GOVERNOR. The governor is an automatic throttle that maintains a constant engine speed by counteracting changes in load. Thus, the frequency output of the generator is kept constant.

The AIR-HEATER SWITCH controls the current to an ignition system in the air-heater unit installed in the engine. The air-heater unit preheats the ingoing charge of air to the cylinders. This unit is used only for cold-weather starting. The air-heater switch is turned off after the engine has started. It is common practice to preheat the large diesel engines for cold-weather starting. In one preheating method, an AIR-HEATER PUMP is used in conjunction with the air-heater switch. Operating this pump causes oil to flow under pressure from the air-heater unit spray nozzle. The ignition system in the air-heater unit ignites the oil spray. The heat from this miniature oil burner warms the ingoing charge of air.

The ELAPSED-TIME METER indicates the number of hours the engine is in operation. You will record the reading of the elapsed-time meter in the log. It is used to determine when the engine is ready for maintenance or lubrication.

The OIL-PRESSURE GAGE indicates the engine oil pressure. A quick look at this gage tells you the condition of your lubricating system. The normal operating pressure averages about 30 pounds per square inch.

The WATER-TEMPERATURE GAGE indicates the temperature of the cooling water in the engine. The water temperature should read 160-185°F under normal operation of nonpressurized systems.

The BATTERY-CHARGING AMMETER indicates the amount of current sent over to the

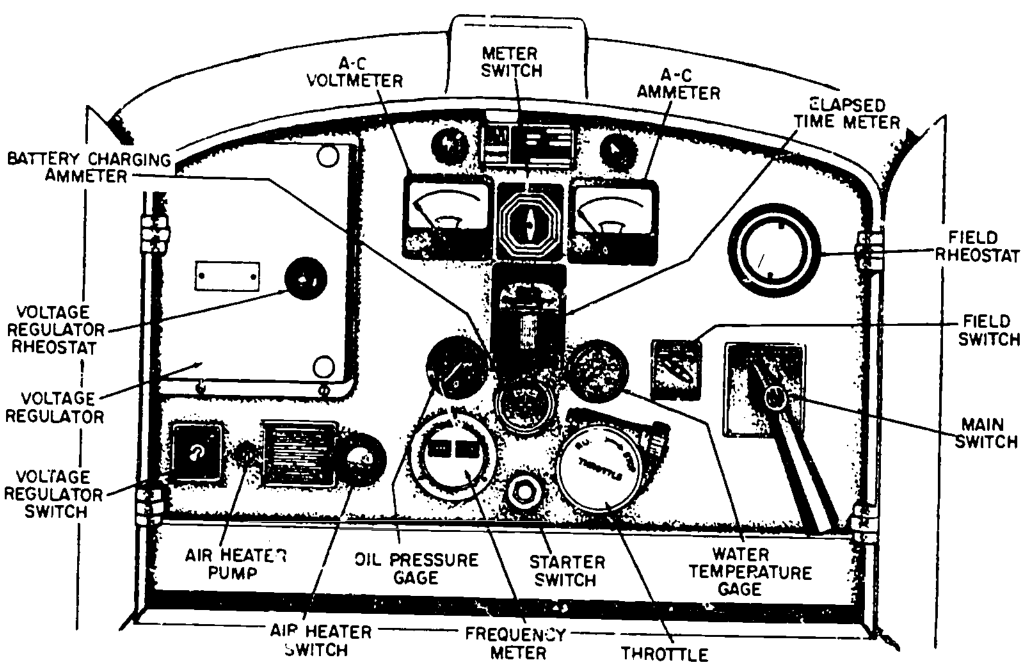

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Figure 9-5.—Control panel for single diesel-driven generator unit.

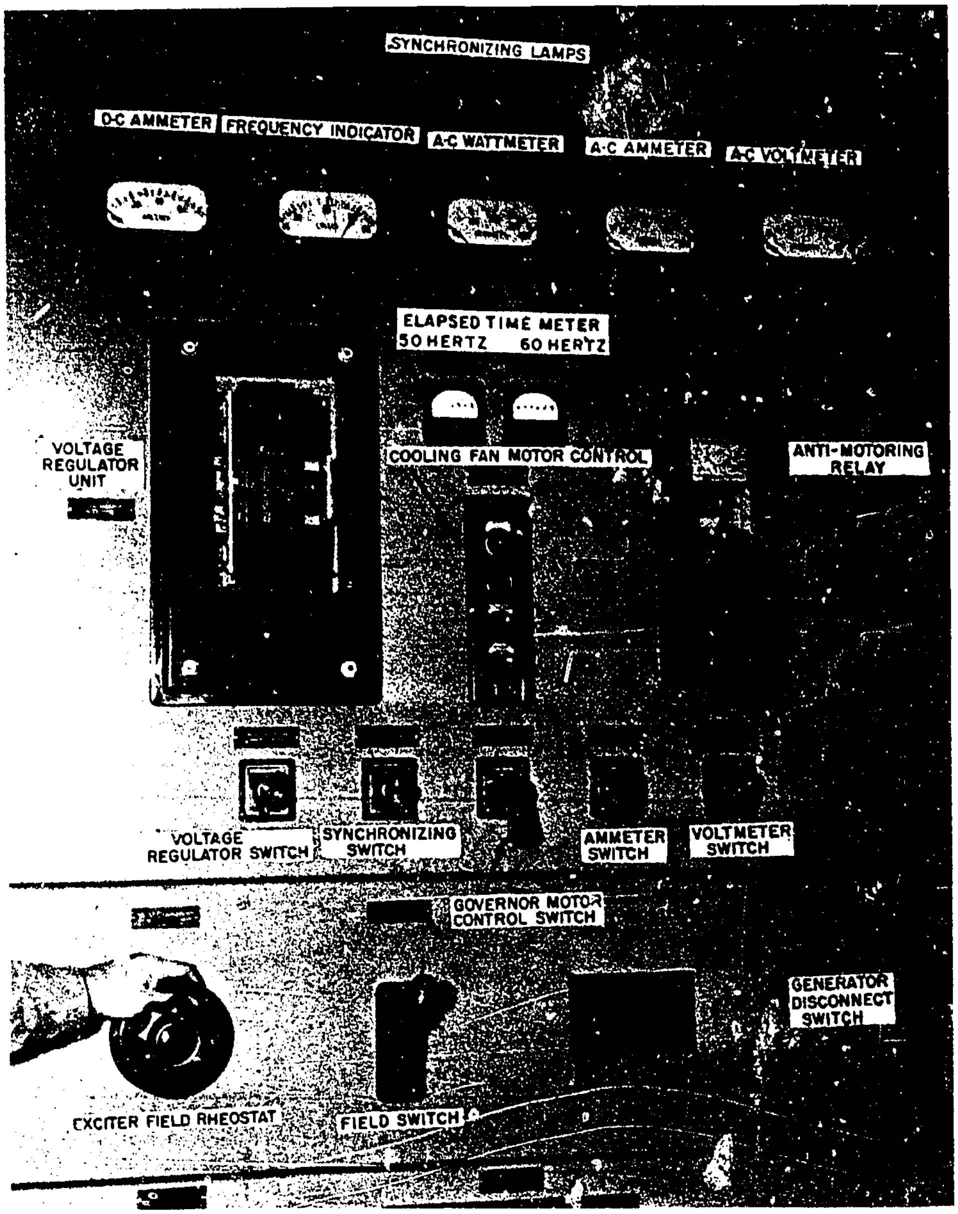

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Figure 9-6.— Control board of a single generator in a central power plant.

battery from the charging generator. It also indicates the amount of current being delivered by the battery on discharge.

The FIELD SWITCH controls the output of the exciter. In the OFF position, the switch disconnects the exciter field from the exciter armature. In the ON position, the exciter field is connected to the exciter armature. Since the exciter supplies current to the alternator-field coils, the field switch also controls the alternator output. Before the engine is stopped, the field switch is thrown to the OFF position. This action disconnects the exciter field and at the same time shunts a FIELD-DISCHARGE RESISTOR across the exciter-field coils. The field-discharge resistor absorbs any high voltages which might result from the quick opening of the field circuit.

The FIELD RHEOSTAT is a manually controlled variable resistor that is placed in series with the exciter field. It controls the voltage output of the exciter. The value of the exciter voltage determines the amount of exciter current flowing in the alternator field coils. The amount of exciter current, in turn, controls the voltage output of the alternator. Thus, when you adjust the field rheostat, the result is seen as an increase or decrease of the voltage output of your generator unit.

The VOLTAGE REGULATOR also serves to control the voltage. It makes your generator watch an easy job. Without the voltage regulator it would be necessary for you to change the field-rheostat setting each time the output voltage of your generator unit varied from its normal value. The voltage regulator does this for you automatically. Like the field rheostat, the voltage regulator is a variable resistance in series with the exciter field. The resistance is varied automatically by a control unit. The control unit takes changes in generator voltage and converts them to changes in mechanical motion. The changes in mechanical motion will increase or decrease the voltage regulator resistance. In this manner the output of your generator is kept at a constant value.

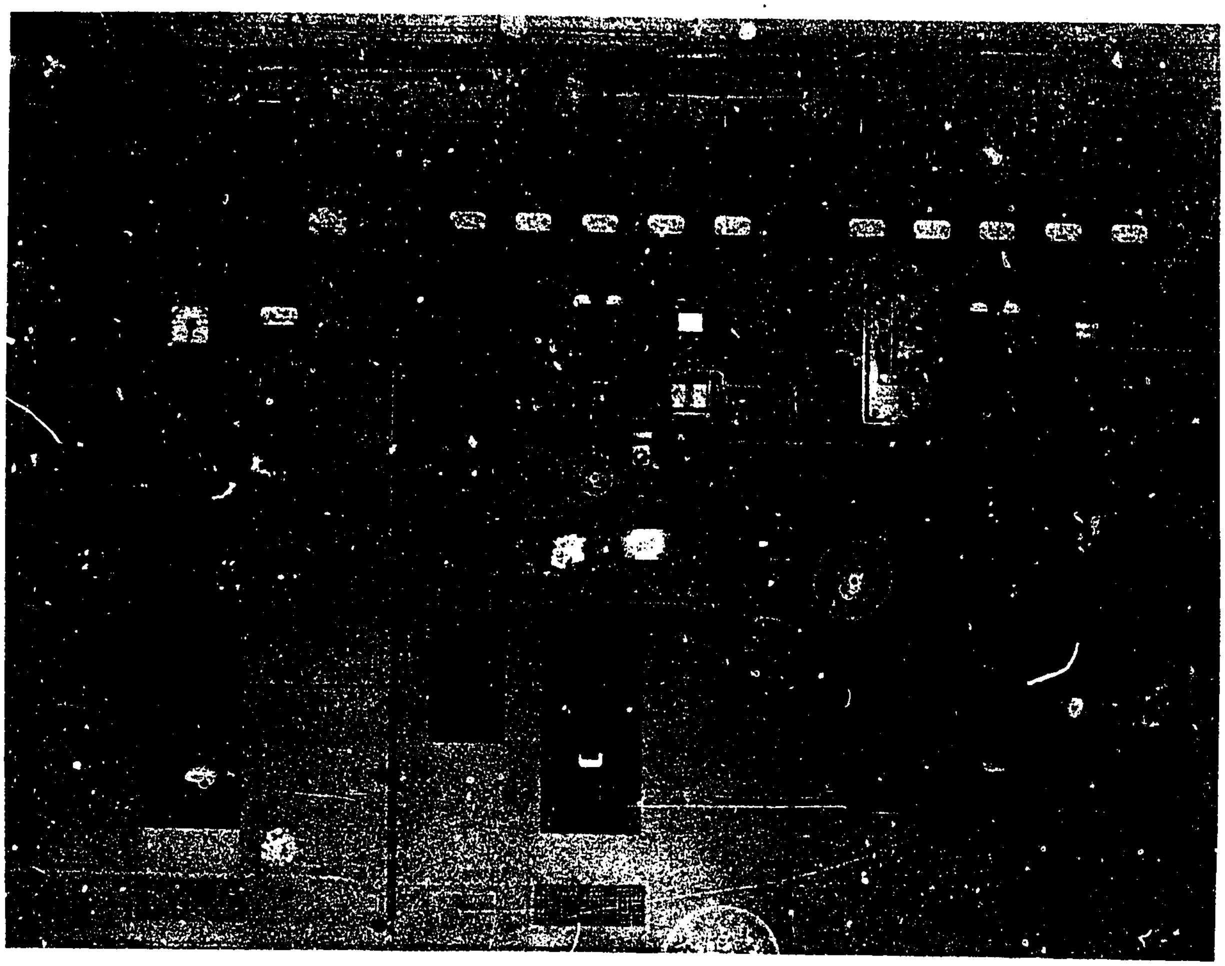

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Figure 9-7.—Switchgear unit for central power station.

The VOLTAGE-REGULATOR SWITCH in the ON position puts the voltage-regulator unit to work. With the switch in the OFF position you must use the field rheostat to adjust the voltage output of the generator unit.

The VOLTAGE-REGULATOR RHEOSTAT is a small variable resistor mounted on the voltage-regulator unit. It is in operation only when the voltage regulator is in the circuit. The setting of the voltage-regulator rheostat determines the value of voltage kept constant by the voltage regulator.

The A-C VOLTMETER indicates the voltage output of your generator unit. When you adjust your field rheostat or voltage-regulator rheostat you will be watching the a-c voltmeter. It will tell you when you have reached the generator's rated voltage output.

The A-C AMMETER indicates the current output of your generator unit. Any overload or unbalancing of a line can be spotted with this instrument.

The METER SWITCH is necessary because this particular unit is a three-phase generator. Each position of the switch puts the a-c voltmeter and the a-c ammeter in a different leg of the three-phase line. Thus you are able to read the voltage across any two legs and the current in any one leg. The OFF position of the switch disconnects the ammeter and voltmeter completely.

The FREQUENCY METER measures the frequency (hertz) of the voltage generated by the alternator.

The SYNCHRONIZING LAMPS are used when the generator unit is being paralleled with another generator.

The MAIN SWITCH opens or closes the circuit between the generator and the load. Remember that it doesn't shut the engine off. In most cases the main switch will have a built-in CIRCUIT-BREAKER. This device will automatically open the main switch whenever a continuous overload current appears on the line.

All of these meters, switches, and controls mounted on the face of a panel board or switchgear unit either control or are controlled by other equipment located behind the board. For example: the output cables from the generator are brought to the back of the switchgear and connected to the line terminals of the main switch. The load terminals of the main switch are connected to the bus bars. These bus bars are bar conductors which serve as collection and distribution points—that is, they receive the power generated by the system, and distribute the same to the distribution circuits leading to the various points of consumption.

SWITCHBOARD CONTROLS

The switchboard instruments should include an indicating wattmeter to avoid the necessity for making numerous ammeter and voltmeter readings to compute power output. If records must be kept on generator efficiency, a watthour meter is also needed.

Remember that the voltmeter measures the voltage of the bus, not that of any one generator contributing to the bus voltage. Ammeters, however, should be connected in series with at least one lead of the output of each generator. If only a single ammeter is available for measuring three-phase current, it must be switched to the different phases.

A group of lamps connected across the bus, and with a center point grounded, provides a

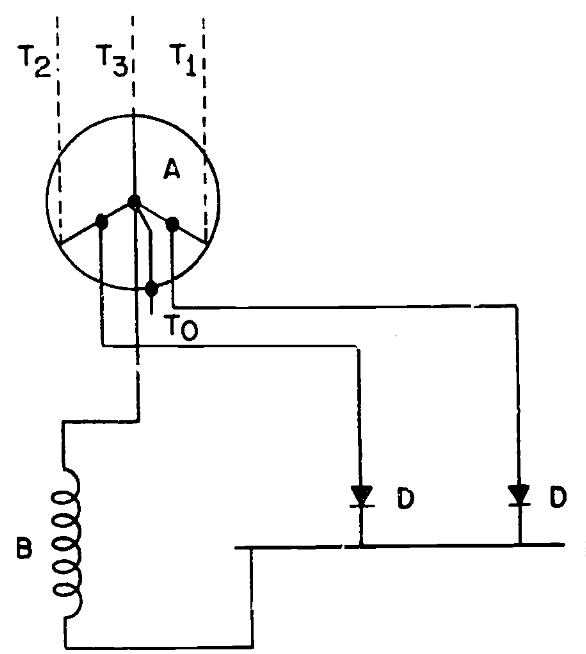

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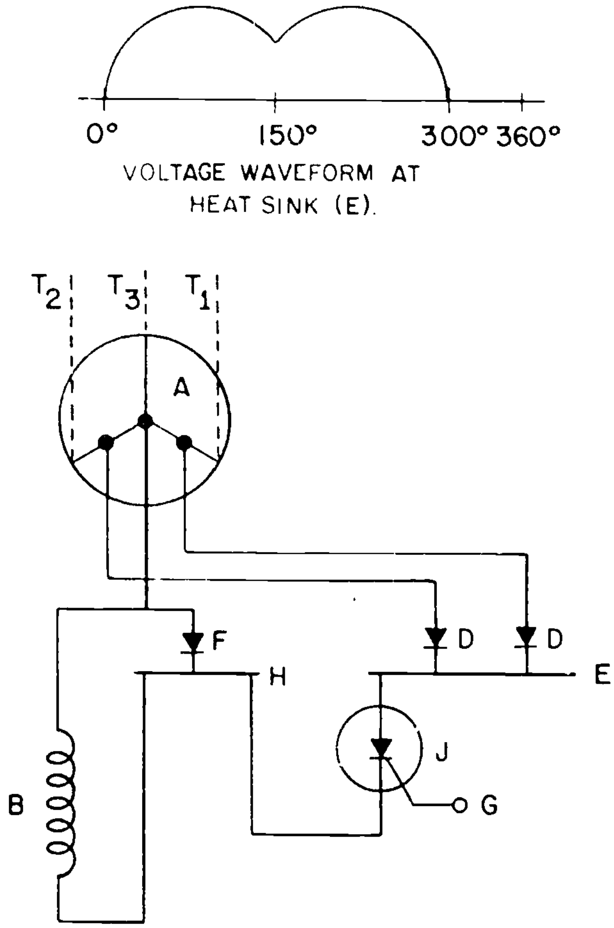
Figure 9-8.—Field excitor.



A-STATOR B-REVOLVING FIELD.
D-POWER RECTIFIER. E-MAIN HEAT SINK.
F-FIELD RECTIFIER. H-AUXILIARY HEAT SINK.
J-CONTROLLED RECTIFIER.

73.338

Figure 9-9.—Field rectifier.

practical means for detecting any accidental ground.

STATIC CONTROLS

In today's field generating plant you will be operating and maintaining Statically Regulated Controlled Rectifier (SRCR) generators. They vary in size and manufacturer, and require less maintenance, are more compact and lightweight, and give better voltage regulation than the older types which required movable mechanical parts and electrical contact points.

OPERATION THEORY OF SRCR GENERATORS

Residual magnetism in the field poles (fig. 9-8) will allow the generator to produce approximately 3 to 5% of rated voltage. Two of the three phases are tapped to provide a-c for the field excitation. Two power rectifiers (D) change this to d-c and are mounted on the main heat sink (E). The direct current from the power rectifiers is fed through brushes and slip rings to the field windings (B) and adds to the residual magnetism to increase the output voltage.

Since the generator voltage would increase without control in the circuit as shown, a method of limiting and controlling is required. The field rectifier (F) in figure 9-9 mounted on an auxiliary heat sink (H) maintains field current flow when the excitation voltage drops to zero

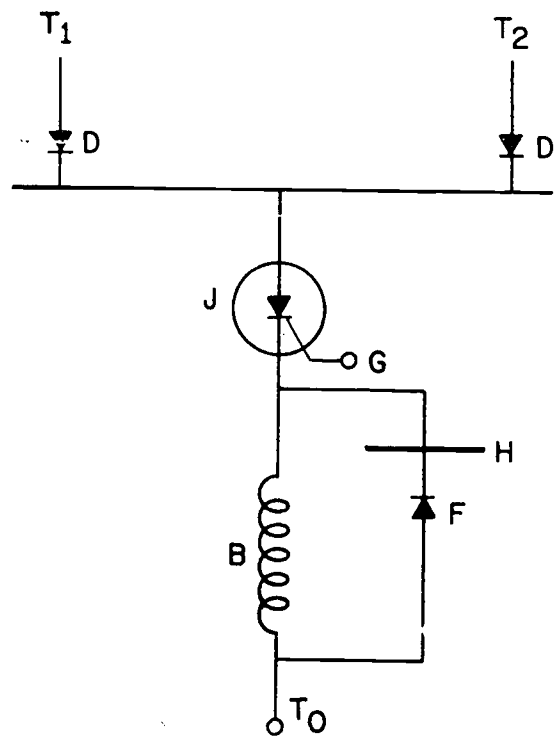


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Figure 9-10.—Controlled rectifier.

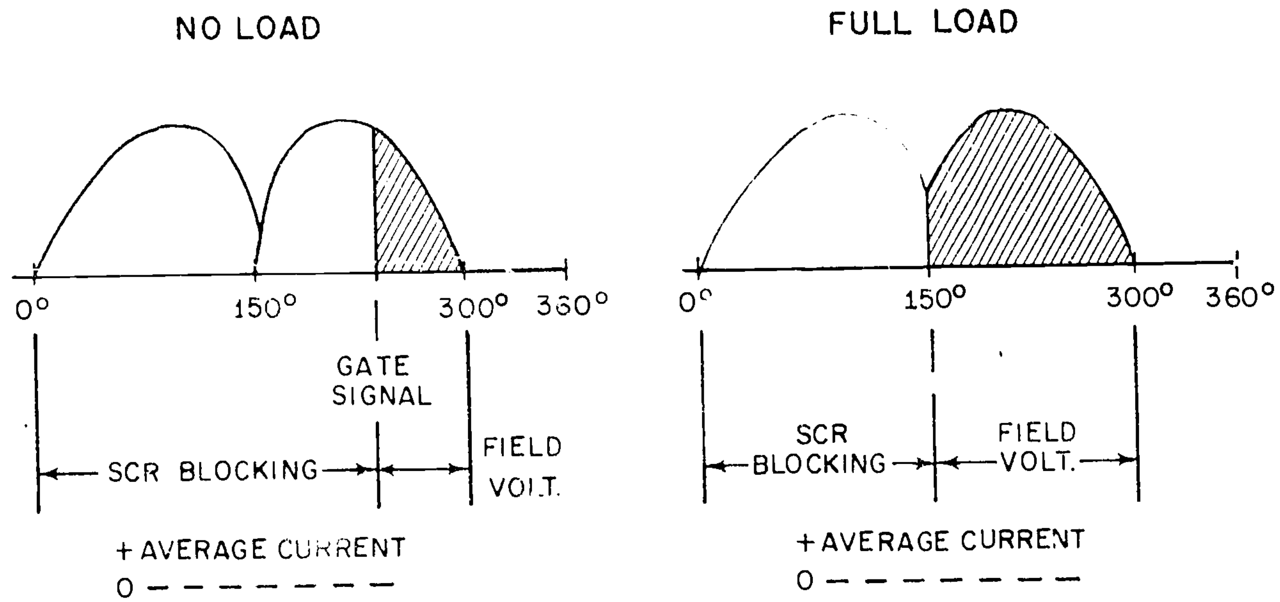

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Figure 9-11.—Field current.

for 60° of field rotation. This current flow is due to the collapsing magnetic field which represents stored electrical energy.

The silicon controlled rectifier (J) in the field circuit (figs. 9-9 and 9-10) provides the means of controlling field current, hence output voltage. This rectifier will not conduct until a positive voltage is applied to the gate terminal (G). It has to be turned on every cycle since the 60° time that the voltage is zero turns it off at the end of every cycle. The pulses of current form an average value of current which maintains the generator at rated voltage.

The field current is turned on during each cycle (fig. 9-11). At no load the silicon controlled rectifier (SCR) allows little current to reach the field. At full load the SCR allows a larger current to reach the field.

WARNING

When a statically regulated controlled rectifier generator is running, do not touch the aluminum heat sink assembly on the back of the chassis as it is electrically charged. The rectifier may be damaged if metal contact is made between the heat sink and the generator frame.

VOLTAGE CONTROL CIRCUIT

The voltage buildup relay (L) in figure 9-12 applies a positive voltage to the gate of the rectifier (J) and turns it on when the generator is being started. The closed contacts apply the positive heat sink (E) voltage to the gate of the SCR.

The buildup resistor (BR) is a piece of nichrome wire on the relay socket base.

Blocking diode (BD) protects the rectifier (J) from failure in case the power rectifiers (D) short.

The relay contacts open when the generator reaches 60% of the rated voltage. The regulator assembly (X) controls the rectifier (J) after the voltage builds up.

Regulator Assembly (X) turns on the rectifier (J) every cycle (60 times per second) to allow field current to flow. The amount the regulator assembly allows current to flow depends on the generator load. The regulator assembly changes the amount of field current flowing by turning on the rectifier (J) sooner or later in the cycle.

The regulator assembly contains a voltage level sensing circuit and a SCR triggering circuit. The triggering circuit does the actual triggering of the SCR but the voltage level sensing circuit tells the triggering circuit when to turn the SCR on.

The voltage level sensing circuit in figure 9-13 which feeds a signal into the regulator assembly (X), contains the following parts.

1. A voltage level potentiometer (N) provides a means of adjusting the voltage level. The voltage level is changed by adjusting the amount of voltage applied to the regulator assembly through the isolation transformer (P).

2. Sensing reactor (M) makes the regulator circuit independent of generator frequency. The regulator responds now at the same rate as the engine governor.

3. Isolation transformer (P) isolates the regulator assembly from the rest of the generator.

4. Filter choke (Q) increases the stability of the regulator assembly by smoothing out the voltage that the voltage sensing circuit sends to the triggering circuit.

5. Voltage droop transformer (T) provides the additional control circuit voltage required to produce the desired voltage droop when operating in parallel.

6. Voltage droop potentiometer (U) controls the amount of voltage droop added to the regulator.

By sensing the generator field current, the regulator gain control (S) holds the generator voltage constant as the engine speed droops from no load to full load. The generator field current produces a voltage droop across the regulator gain resistor (R) and the gain control is in parallel with the resistor.

The noise suppression assembly (V) eliminates the radio static produced by the generator. The noise suppressor has coils in series with the lines and capacitors connected to ground. An additional surge suppressor is connected across the field rectifier (F) to protect it from short high voltage pulses.

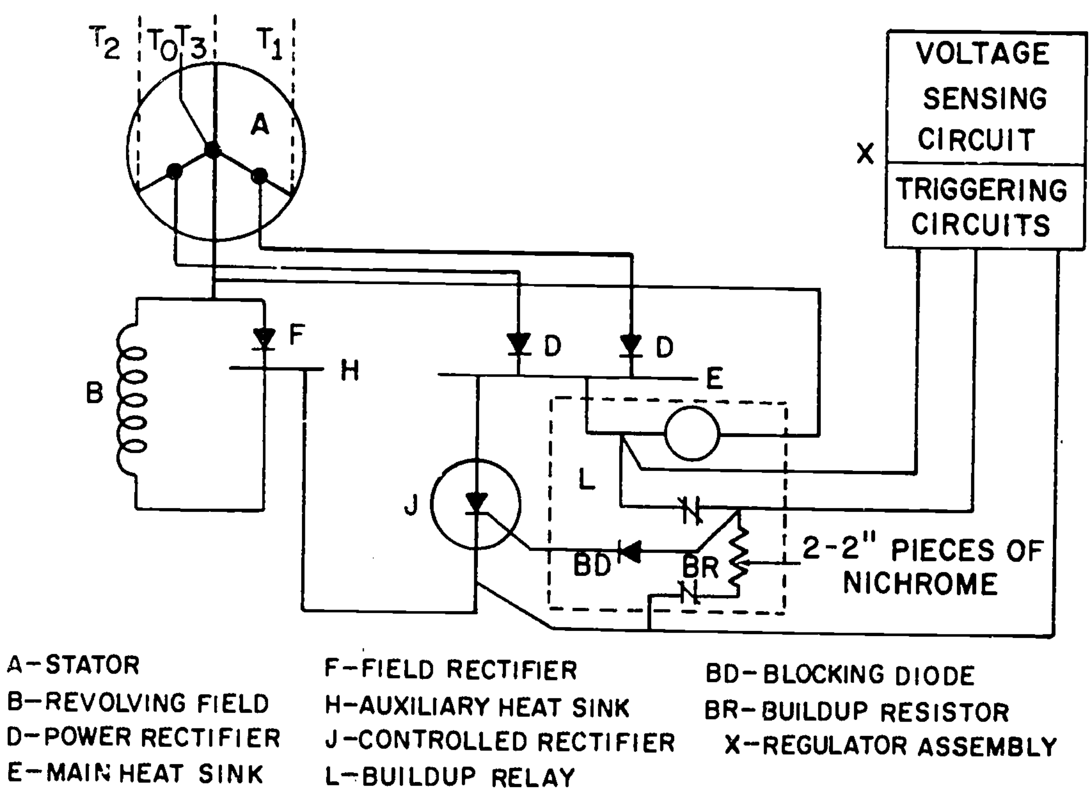

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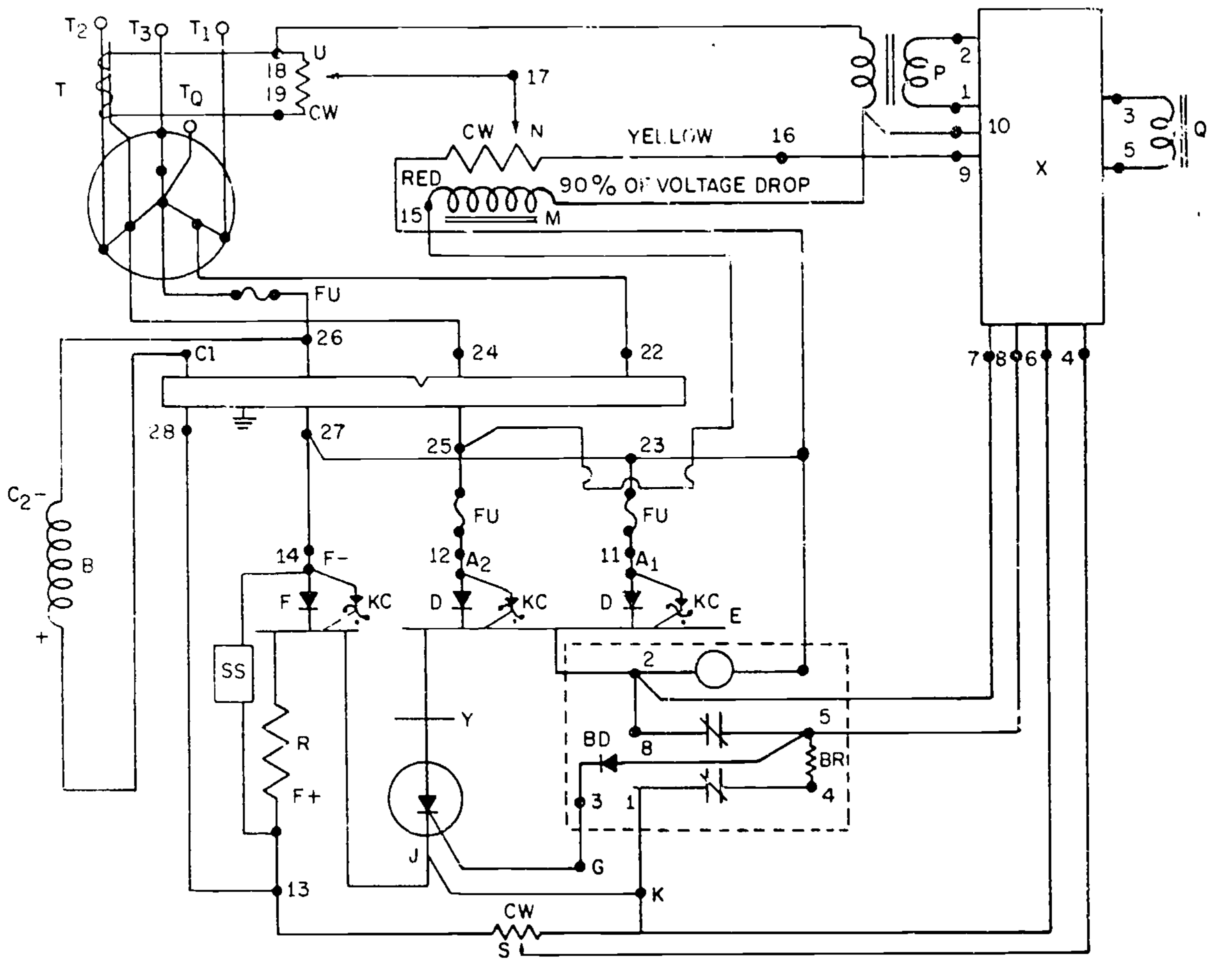
Figure 9-12.—Voltage buildup relay.



A-STATOR
B-ROTATING FIELD
D-POWER RECTIFIER
E-MAIN HEAT SINK
F-FIELD RECTIFIER
H-AUXILIARY HEAT SINK
J-CONTROLLED RECTIFIER

L-BUILD-UP RELAY
M-SENSING REACTOR
N-VOLTAGE LEVEL POTENTIOMETER
P-ISOLATION TRANSFORMER
R-REGULATOR GAIN RESISTOR
S-REGULATOR GAIN POTENTIOMETER
T-VOLTAGE DROOP TRANSFORMER

U-VOLTAGE DROOP TRANSFORMER
V-NOISE SUPPRESSION ASSEMBLY
X-REGULATOR ASSEMBLY
Y-CONTROLLED RECTIFIER HEAT SINK
SS-SURGE SUPPRESSOR
FU-FUSE
KC-KLIP-CEL VOLTAGE SURGE SUPPRESSOR

73.342

Figure 9-13.—SRCR control.

The fuses (FU) are extremely fast blowing to protect the circuit from high current.

The klip-cels (KC) reduce voltage pulses across the rectifiers. The voltage pulses could occur when large loads are disconnected from the generator.

Instrument Transformers

The voltage and currents delivered by a generating system to the bus bars are too high for safe operation of most of the switchboard apparatus, particularly the switchboard instruments. Instrument transformers, therefore, are mounted on the back of the switchboard and connected to the bus bars. Their purpose is to step down the voltages and currents fed to instruments, relays, voltage regulators, and the like. By the use of transformers, switchboard apparatus can be insulated from the high-voltage circuit, yet receive enough power to indicate accurately the voltage, current, and power in the circuit.

Transformers used to reduce high current values to the small values required to operate ammeters, or to operate current coils in other instruments, are called current transformers. Transformers which reduce high voltages to smaller voltages required to operate voltmeters or the potential coils of other instruments are known as "voltage" or "potential" transformers.

The primary winding of a current transformer may consist of a few turns around a laminated iron core, or it may, in some cases, consist of the bus bar or cable carrying the line current. The primary winding is always connected in series with the line.

The secondary winding consists of several turns of relatively small wire wound around a laminated core. It is the secondary, of course, that is connected to the ammeter or other instrument or switchboard device. The current rating of the secondary on practically any current transformer is 5 amperes, regardless of the current rating of the primary.

The secondary of a current transformer should never be open-circuited while the primary is energized. An open-circuited current transformer might develop several thousand volts across the secondary, where there would be only a few millivolts (a millivolt is 0.001 volt) if the secondary circuit were closed. This high voltage might well cause severe, even fatal, shock to the operator. It would in any case break down insulation and destroy the transformer. Hence the invariable rule: NEVER OPEN THE SECONDARY OF A CURRENT TRANSFORMER WHEN IT IS CONNECTED IN THE CIRCUIT.

Potential (voltage) transformers have a low current rating. The low side of the transformer is usually wound for 110 volts, and the ratio of turns on one side to turns on the other is determined by the rating of the high-voltage side. The primary is connected across the voltage source to be measured, and the secondary is connected to the meter or other instrument or device. The current through the potential transformer depends on the load of the meter or other device. This load is always constant.

The secondary should always be grounded at one terminal, to eliminate static from the measuring instrument, and also to protect personnel. Again there is an important safety precaution: NEVER SHORT-CIRCUIT THE SECONDARY OF A POTENTIAL TRANSFORMER.

Synchroscopes

The SYNCHROSCOPE is a phase relation meter connected so as to measure the phase

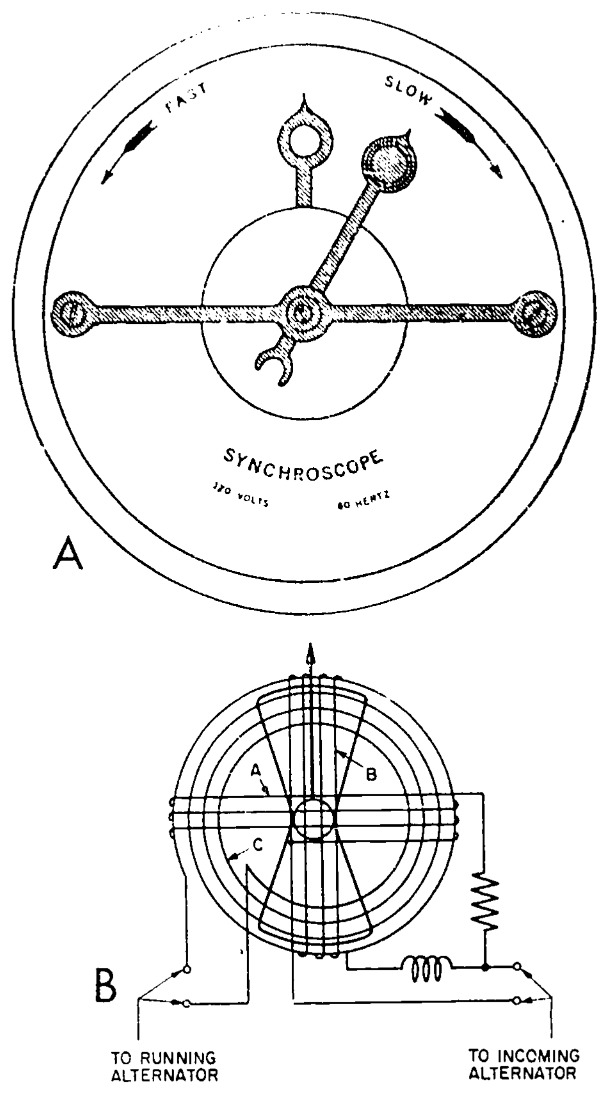


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Figure 9-14. — Dial face and wiring diagram of a synchroscope.

relation between generator voltage and bus bar voltage when an additional generator is being put on the line.

With a synchroscope you determine (1) whether the frequencies of the alternators are the same or different, (2) whether frequency is constant for an appreciable time, and (3) whether or not the voltages of both generators are in phase — that is, whether they reach maximum value at the same time.

Figure 9-14A shows the dial of a synchroscope, figure 9-14B a wiring diagram of the instrument. Coils A and B are connected to the incoming generator through a potential transformer. Coil C is connected to the bus line. One pointer holds a fixed position at the top of the dial as shown in figure 9-14. The moving element is attached to the second, movable pointer. If the frequencies are the same, this pointer takes a fixed position. With any slight variation in frequency, however, it will begin to travel — toward SLOW if the incoming generator is slow, toward FAST if it is fast. The amount of difference in frequency is indicated by the speed of travel.

BRUSHLESS GENERATORS

Figure 9-15 shows an elementary circuit diagram for a brushless generator system. Elimination of brushes, slip rings, and commutators is accomplished by placing a rectifier assembly, generator field and exciter armature on the rotor.

In the brush type of a-c generator (fig. 9-16), the field current is transferred from the rotating part of the machine to the generator field by the use of commutator, brushes and collector rings. Much time is spent on the maintenance of these components.

Brushless type rotating exciters (fig. 9-17) eliminate the necessity for commutator, collector rings and brushes by applying the a-c output of the exciter armature to silicon rectifiers connected in a bridge. The d-c rectified output is then applied directly to the field. Since

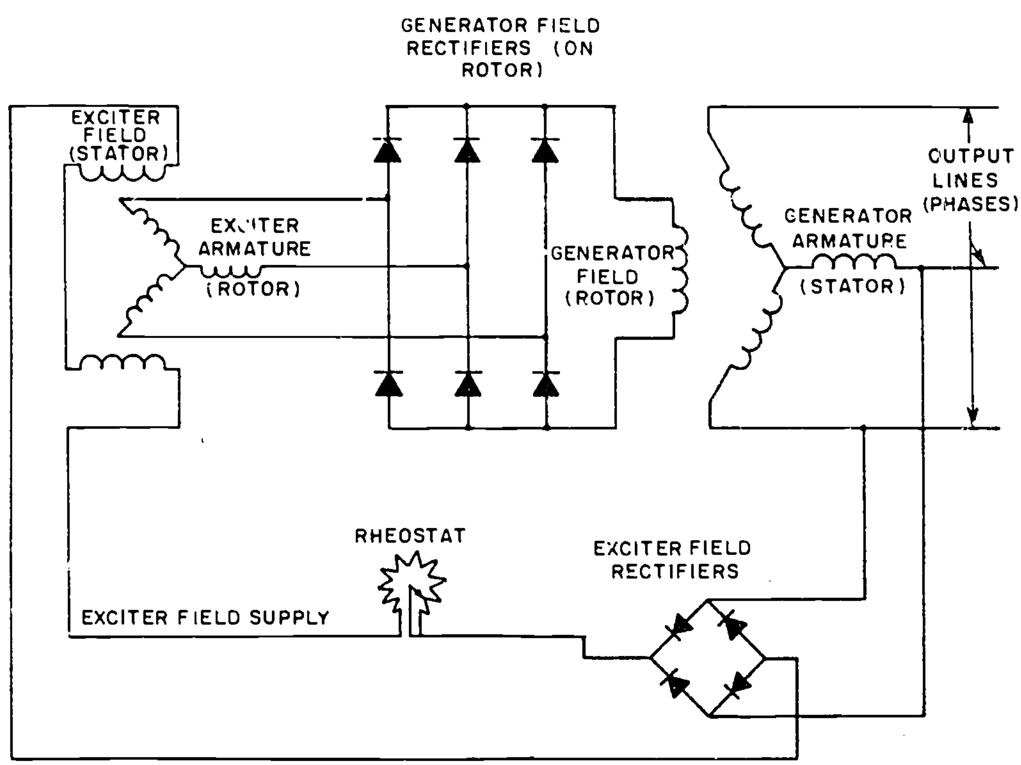

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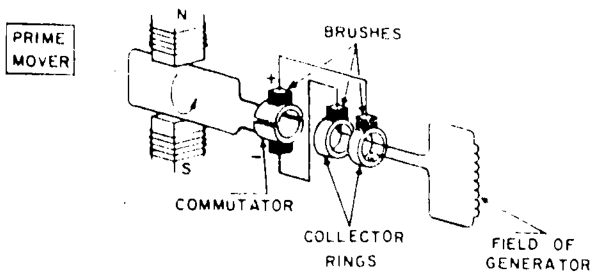
Figure 9-15. — Brush type rotating exciter.



73.308
Figure 9-16.—Basic brushless generator.

all these components are mounted on the rotor, no need exists for brushes, commutator or slip rings, making the entire unit compact, simple, and free of sparking. Maintenance is thus reduced.

GENERATOR INSTALLATION

In setting up the generator try to place the equipment near points of large demand, to reduce the size of wire required, to hold the line losses to a minimum, and to afford adequate voltage control at the remote ends of the lines. Generators must not be closer than 25 feet to a load, because of noise, fire hazard, and air circulation.

Moving the generator may be accomplished by lifting or pulling (fig. 9-18). The generator set comes equipped with a lifting sling usually stowed in the skid on the side of the unit opposite the operator's control panel.

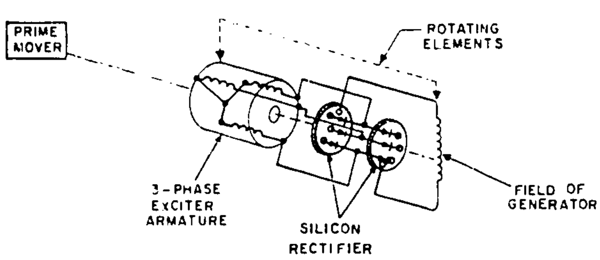


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Figure 9-17.—Brushless type rotating exciter.

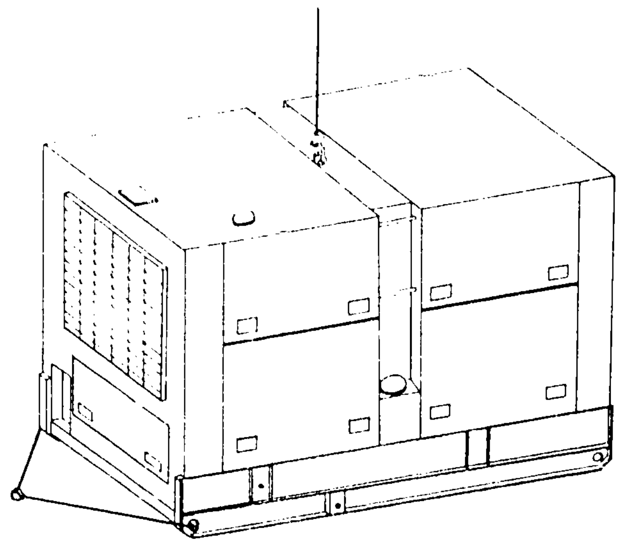

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Figure 9-18.—Towing and lifting slings.

POWER AND VOLTAGE REQUIREMENTS

The power and voltage requirements of the load will normally determine the size of the generator to be used. For example, electrical equipment rated at 120 volts, single phase with a combined power load of less than 1500 watts can be adequately handled by a gasoline- or diesel-driven power plant with a 120-volt, 2-wire output rated at 1.5 kw. If the power demand of the equipment is greater than 1.5 kw, but does not exceed 4.5 kw, a generator rated at 5 kw, 120 volts, with a 2-wire output can be used.

The selection of voltage is affected by the size, character, and distribution of the load; length, capacity, and type of transmission and distribution circuits; and size, location, and connection of generators. Practically all general purpose lighting in the United States and at United States overseas bases is 120 volts. The lighting voltage may be obtained from a 3-wire, 120/240-volt, single-phase circuit or a 120/208-volt, three-phase, 4-wire circuit. Some small motors can be supplied by direct current or single-phase alternating current at nominally 120 volts. Large three-phase, a-c motors, above 5 horsepower, will generally operate satisfactorily at any voltage between 200 and 240.

Demand Factor

Electrical loads are generally measured in terms of amperes, kilowatts, or kilovoltamperes. In general, electrical loads are seldom constant for any appreciable time, but fluctuate constantly.

The connected load is the sum of the rated capacities of all electrical appliances, lamps, motors, and so on, connected to the wiring of the system. The maximum demand load is the greatest value of all connected loads that are in operation over a specified period of time.

The ratio between the actual maximum demand and the connected load is called the demand factor. If a group of loads were all connected to the supply source and drew their rated loads at the same time the demand factor would be 1.00. There are two main reasons why the demand factor is usually less than 1.00. First, all load devices are seldom in use at the same time, and even if they are, they will seldom reach maximum demand at the same time. Secondly, some load devices are usually slightly larger than the minimum size needed and normally draw less than their rated load.

Power Factor

Power factor (PF) is a ratio or percentage relationship between watts of a load and the product of volts and amperes necessary to supply that load. Watts (W), the measure of actual power, is the product of volt and ampere values at any one instant. Volt-amperes, the measure of volts (E) and current (I) on the line, is the product of the units, regardless of their time displacement. These products are also referred to as true power (watts) and apparent power (volt-amperes).

$$\text{Power factor} = \frac{\text{true power}}{\text{apparent power}} = \frac{\text{watts}}{\text{volt-amperes}} = \frac{W}{E \times I}$$

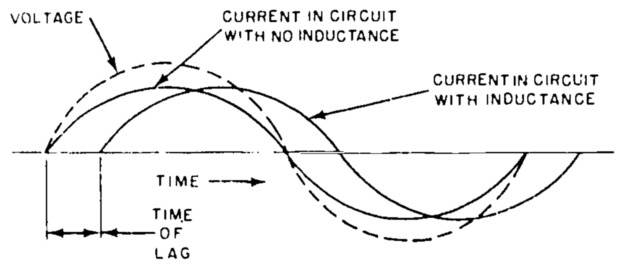
For single-phase circuits

$$W = E \times I \times PF \text{ or } I = \frac{W}{E \times PF}$$

For 3-phase circuits, the constant 1.73 must be introduced into the equation. Therefore,

$$I = \frac{W}{E \times PF \times 1.73}$$

Inductance in a circuit lowers the power factor by causing the current to lag behind the voltage, as illustrated in figure 9-19. If the voltage and current curves start together, reach maximum at the same time, and pass through 0 together, the circuit has a power factor of 1 or 100%.



26.245

Figure 9-19.—Inductance makes current lag behind voltage.

A power factor of 1 or 100% means that no time lag exists and that watts equals volt-amperes. A 50 percent power factor means that watts are only 1/2 the volt-ampere product and that twice as much current is required to produce a given amount of power, compared with 100 percent power factor.

The power factor is illustrated in figure 9-20 which shows a railroad car being pushed by a locomotive. If the locomotive were on the same track pushing directly from behind it, all the force would be useful work. However, if the locomotive is on a parallel track as shown, the amount of force may be the same, but the actual push on the car is not the same because some force tends to push the car sideways off the track. The power output from the locomotive is divided between actual work and the lost force. In other words, real power is less than apparent power. The situation is similar to that of an electrical circuit where time lag exists and the real or true power is less than the apparent power.

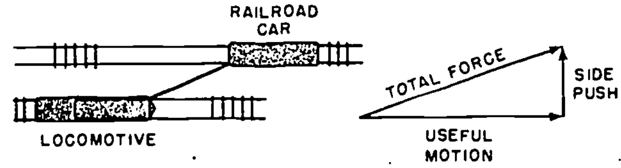


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Figure 9-20.—Illustration of power factor.

Power loads from drive motors and constant-current regulators reduce the power factor most because they require large amounts of reactive power in their operation. Reactive power is apparent power used by inductive loads, that is, inductance in a circuit. Other appliances, such as welders, may also require reactive power. Loads, such as electric heaters and heating appliances, that are due to resistance only do not affect the reactive power.

SHELTERING GENERATORS

Although advanced base portable generators are designed to be operated outdoors, prolonged exposure to wind, rain, and other adverse conditions will definitely shorten their life. If the generators are to remain on the site for any extended period of time, they should be mounted on solid concrete foundations and should be installed under some type of shelter.

There are no predrawn plans for shelters for a small advanced base generating station. The shelter will be an on-the-spot affair, the construction of which is determined by the equipment and material on hand plus your ingenuity, common sense, and your ability to cooperate with men in other ratings. Before a Builder can get started on the shelter, you will have to furnish information, such as the number of generators to be sheltered; the dimensions of the generators; the method of running the generator load cables from the generator to the bus bar and from the bus bar to the feeder system outside the building; and the arrangement of the exhaust system.

Large generator units may have, connected or attached to them, engine equipment that requires extra space and working area. Included in this equipment are: air-intake filters, silencers for air intake and exhaust, fuel and lubricating oil pumps, tanks, filters and strainers, starting gear, isochronous regulating governors with overspeed trips, safety alarm and shutdown devices, gages and thermometers, turning gear, and platforms, stairs, and railings.

An even larger and more complete power plant may require separate equipment, such as a motor-driven starting air compressor and air storage tanks; motor-driven pumps for jacket water and lubricating oil cooling, or heat exchangers with raw cooling water pumps and lubricating oil coolers; and tanks, including day-fuel storage.

Installation specifications are available in the manufacturer's instruction manual that accompanies each unit. Be sure to use them. Consulting your Builder about these specifications may help cut installation costs and solve piping problems.

The following hints and suggestions will also be helpful.

1. Consider ventilation when installing the units inside a building. Every internal combustion engine is a HEAT engine. Although heat does the work, excess amounts of it must be removed if the engine is to function properly. This can be accomplished by setting the engine's radiator grill near an opening in the wall and providing another opening directly opposite the unit. In this manner, cool air can be drawn in and the hot air directed in a straight line outdoors. These openings can be shielded with adjustable louvers to prevent the entrance of rain or snow. In addition, when operating in extremely cold weather, the temperature in the room can be controlled by simply closing a portion of the discharge opening. Additional doors or windows should be provided in the shelter if the plants are installed in localities where the summer temperatures exceed 80°F at any time.

2. Be sure to provide enough working space around each unit for repairs or disassembly and for easy access to the generator control panels.

3. Do not allow carbon monoxide gas to collect in a closed room; this gas is extremely poisonous. Discharge the engine's exhaust to the outdoors by extending the engine's exhaust pipe through the wall or roof of the building. Support the exhaust pipe and make certain that no obstruction or too many right angle bends are used. Also, whenever possible, arrange the exhaust system so that the piping slopes away from the engine. In this way, condensation will not drain back into the cylinders. If the exhaust pipe should have to be installed so that loops or traps are necessary, a drain cock should be placed at the lowest point of the system. All joints must be perfectly tight, and where the exhaust pipe passes through the wall, care must be taken to prevent the discharged gas from returning along the outside of the pipe back into the building. Exhaust piping inside the building must be covered with insulation capable of withstanding a temperature of 1500°F.

ELECTRICAL INSTALLATION

As a CE your prime concern will be with the electrical installation. You will have to insure the generator is in good working order, grounded properly, connected for the proper output voltage, and protected against overloads and shorts when tied to the load.

GROUNDING

The metal cabinet in which each power panel is mounted, and the neutral bus in the switchgear unit, must be grounded. However, there are many metal noncurrent-carrying parts of the distribution system that must be grounded as well. It is the custom, therefore, to draw up a plan or system which will ensure grounding of all metal parts, such as the bases and frames of motors and generators, the steel tanks of distribution transformers, switchgear apparatus, and any other metal parts which might permit development of an electrostatic field.

Figure 9-21 shows a representative grounding plan. The dotted lines represent grounding cables. The letter "R" denotes the locations of driven ground rods. The letter "A" indicates points at which branch cables are connected to the equipment. Bare stranded copper cable is used throughout the system, with size 1/0 AWG used for the main ground and for the branch cables.

The preferred ground is a buried metallic water piping system. In the absence of such a piping system, a driven solid metal rod, a driven metal pipe, or a buried metal plate can be the ground. The ground rod must be at least 5/8 inch in diameter, the ground pipe at least 3/4 inch. Both must be driven into the earth to a depth of 8 feet or more. The ground plate must have a minimum surface area of 2 square feet and be buried at a minimum depth of 4 feet. The rod, pipe, plate, or piping system is bolted or clamped to the ground lead (one end of a No. 6 AWG copper wire). The other end of this lead is connected to the ground stud on the generator set.

The usual method is to install the preliminary features of the grounding system during the early stages of base construction. Cables must be laid and ground rods driven before the concrete foundations and decks are poured. When the power plant has been installed, the branch cables are connected at one end to the equipment and at the other end to the main belt of cable encircling and running through the station. This main cable is earth-grounded at frequent intervals throughout its run (see letter "R" points in fig. 9-21).

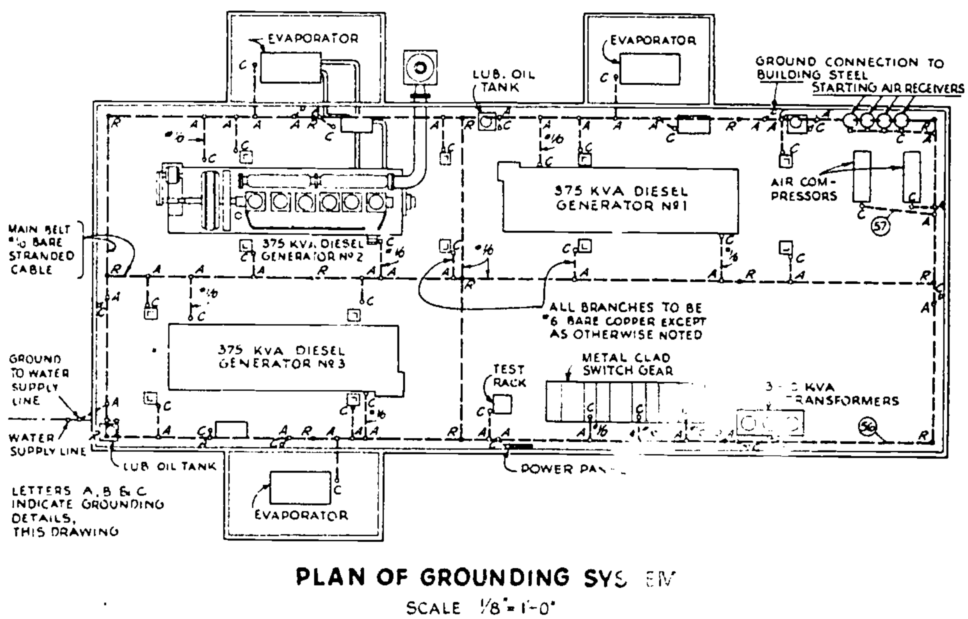

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Figure 9-21. —Representative grounding plan for advanced base power plant.

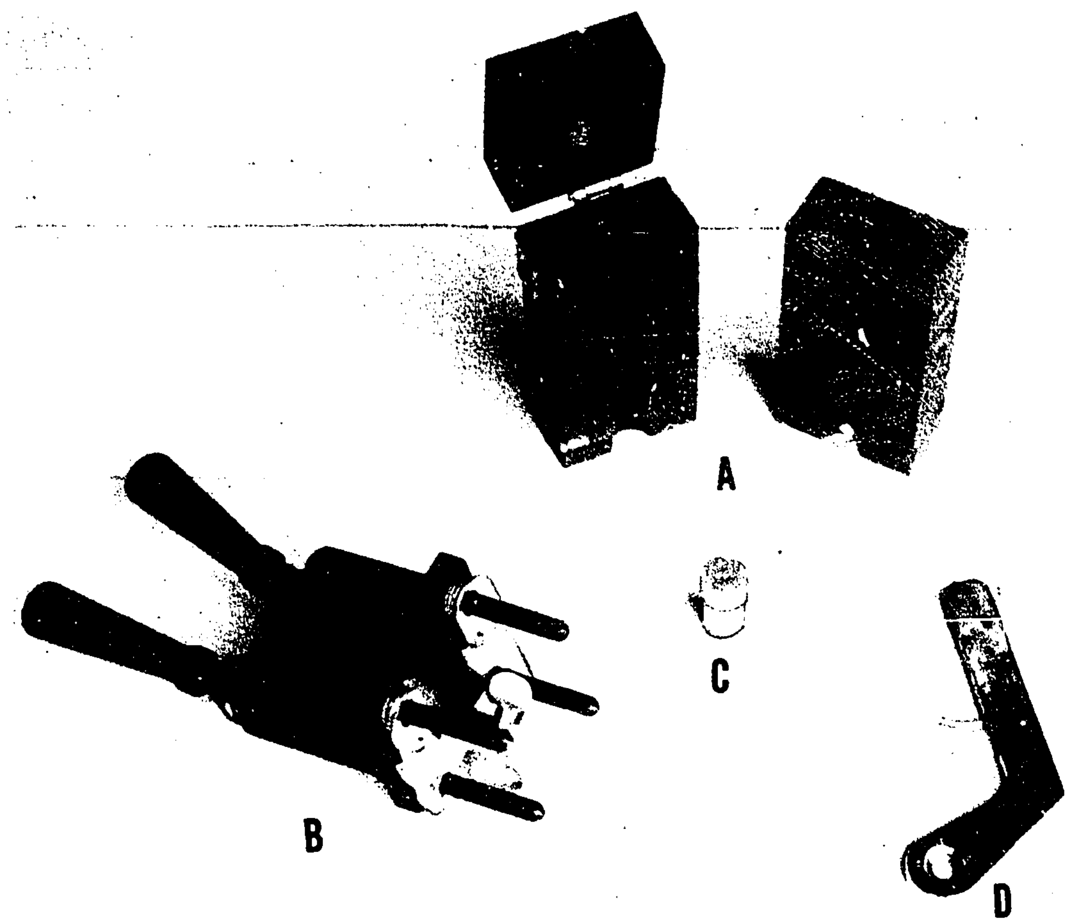

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Figure 9-22.—Equipment and material used for Cadweld process.

One way to connect branch cables to main cables and the main cables to ground rods is by the use of "ground clamps." However, metal clamps tend to corrode, and corrosion causes high resistance (ground resistance must be less than 1 ohm). To overcome this problem, the metal must be cleaned thoroughly and the connection made very tight. Periodic inspections of the connections must be made to ensure that resistance to ground does not develop.

A thermit weld process, called the Cadweld process, is used on Navy installations to eliminate the problem of developing resistance in groundclamp connections. No outside source of power or heat is required for this process. The equipment includes a mold which is clamped over ground rod and cable, or over main and branch cables, at the point of connection. The lower part of this mold has cavities which receive the items to be joined. The upper part has a cavity into which first a metal oxide is poured, and next a starting powder which, upon being ignited, burns at very high temperature. The starting powder is ignited by a spark from a welder's flint lighter. The resulting reaction in the starting powder melts the metal oxide, which flows from the upper recess in the mold into the lower, cools and hardens there, and thus fuses the items to be connected together.

Because the reaction occurs quickly and with high thermal efficiency, the process is ideally suited for joining copper conductors. Normally the weld is completed 10 seconds after the powder is ignited. The short heating process helps protect long conductors against insulation damage due to prolonged exposure to heat.

Figure 9-22 shows Cadweld equipment and material used to weld a ground conductor to a ground rod. A is the mold, B is the clamp which holds the mold in position, C [illegible] the cartridge containing the powdered me[illegible]e and the starting powder, and D is a weld[illegible]s flint lighter. Figure 9-23 shows some welds made by the Cadweld process.

GENERATOR CONNECTIONS

When installing a power plant that has a 220/440-volt, 208/416-volt or other dual-voltage alternator unit, you must connect the armature coil leads properly to produce the voltage required by the equipment. Take a look at figure 9-24. It shows a dual-voltage alternator unit that has been disconnected and removed from a three-phase diesel-driven power plant. The stator or stationary armature coils and core are mounted in the frame of the generator. The a-c voltages generated in the coils are brought through an opening in the pedestal of the frame by means of 10 coil leads. Each coil lead is identified by a number stamped on a metal band.

In a dual-voltage, three-phase generator a voltage is generated in each set of coils, when the prime mover is operating at rated speed. Thus, by connecting the external coil leads together in different combinations, you can change the voltage output of the generator. The chart in table 9-2 gives the exact data needed to make these connections for both three-phase and single-phase voltage outputs.

Let's take a specific example. Suppose it becomes necessary to obtain 220 volts single phase from a three-phase, 220/440-volt generator. Checking table 9-2 you find that coil leads T2 and T8 are to be connected together and then in turn, connected, through the main circuit breaker, to one of the two load cables. Similarly coil leads T3 and T9 are to be secured and connected, through the main circuit breaker, to the other load cable. Leads T5 and T6 are connected together as common point. Terminal lugs on the end of each coil lead provide an easy means of bolting them together. Just be

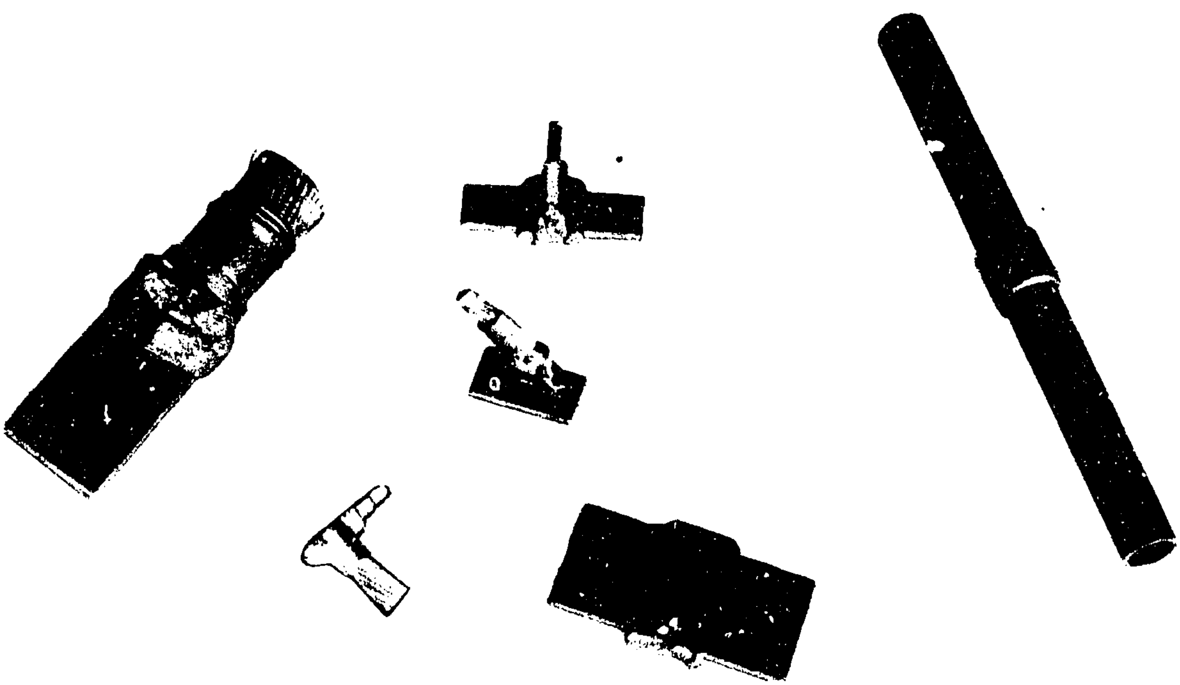

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Figure 9-23. — Welds made by Cadweld process.

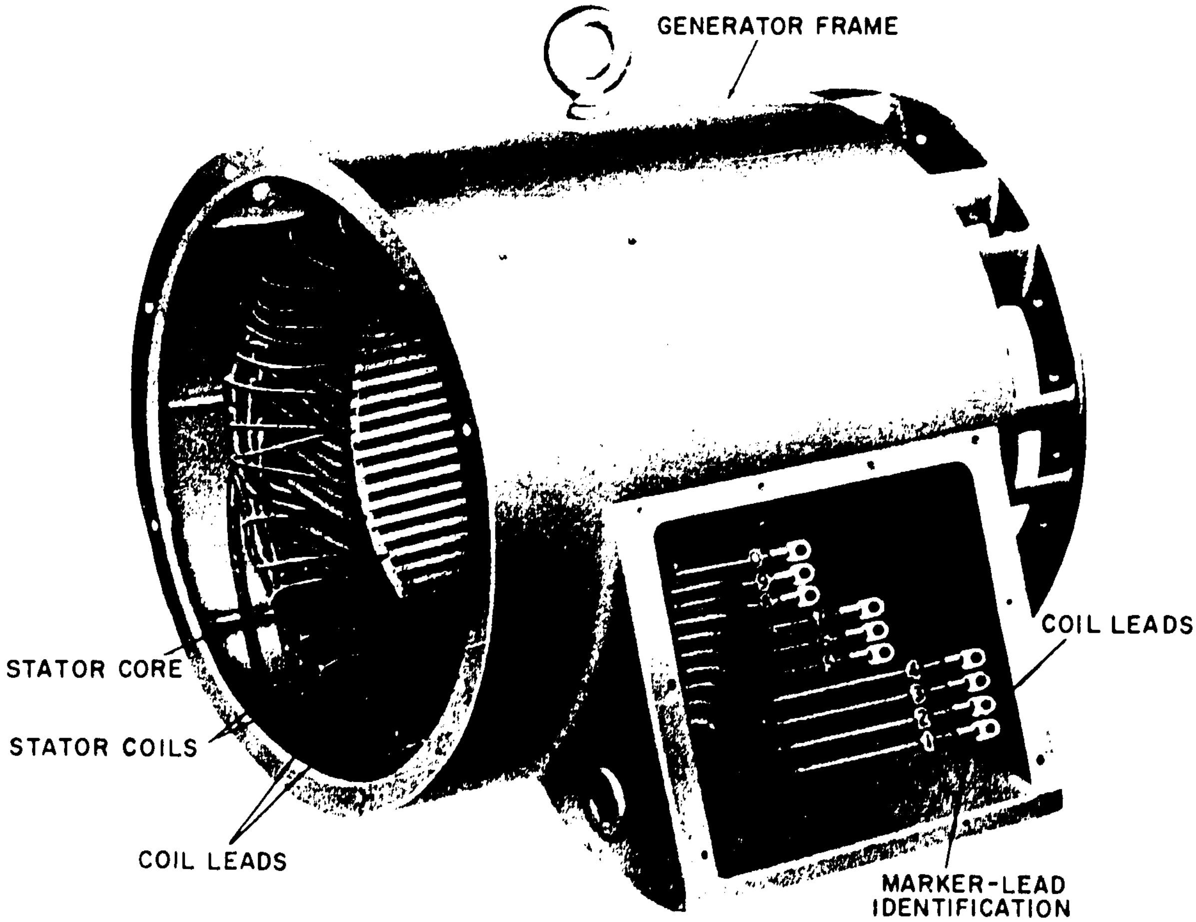

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Figure 9-24.—Alternator coil leads.

Table 9-2.—Connections for Three-Phase Generators

REQUIRED VOLTAGE	CONNECT LINE LEADS (to circuit breaker) TO–			CONNECT	TAPE INDIVIDUALLY
440-VOLTS, THREE-PHASE, 3-WIRE.	T1	T2	T3	T4 TO T7; T5 TO T8; T6 TO T9	
127/220-VOLTS, THREE-PHASE, 4-WIRE.	T1 AND T7	T2 AND T8	T3 AND T9	T4, T5, T6, AND T0 FOR NEUTRAL.	
220-VOLTS, SINGLE-PHASE, 2-WIRE.	T2 AND T8	T3 AND T9	T3 AND T9	T5 TO T6	T1, T4, T7, T0.
220/440-VOLTS, SINGLE-PHASE, 3-WIRE.	T1	T2 AND T9, NEUTRAL.	T8	T5 TO T6	T1, T4, T7, T0.
440-VOLTS, SINGLE-PHASE, 2-WIRE.	T1		T8	T2 TO T9; T5 TO T6	T1, T4, T7, T0.

26.169

sure that the connections are thoroughly insulated with a wrapping of rubber tape followed by a wrapping of friction tape. Table 9-2 indicates that leads T1, T4, T7, and T0 are not used for single-phase service. Therefore, to finish the job, you should individually insulate each of these four leads with rubber and friction tape. Figure 9-25A shows you how the connections appear on the stator coil diagram. Figure 9-25B shows the appearance of the actual connections.

RECONNECTING GENERATOR LEADS

When you reconnect generator leads to meet certain load conditions, you change not only the voltage output of the generator but also its current rating. These voltage and current changes will have an effect on the operational characteristics of the switchboard controls and instruments. Thus, before the generator can be put into operation, other changes must be made.

For example, suppose you have to reconnect a 75-kw, three-phase, 220 volt, generator so that it will have an output voltage of 440 volts. In the original setup (220-volt output), the generator was capable of carrying a full-load current of 264 amperes. Changing over to 440 volts, however, reduces its full-load current to 132 amperes. The first thing you will want to check, then, is the fuse rating in the main switch. You will probably find that for the original 220-volt, 264-ampere setup, the generator was protected by a 275-ampere fuse. To protect the generator for its new current rating (132 amperes), you must replace the 275-ampere fuse with one having a 150-ampere rating.

Another thing to consider when reconnecting a generator is the switchboard ammeter instrument that records the current output of the unit. Since it is impractical to use an ammeter capable of carrying the full-load current, instrument transformers are used. An instrument transformer reduces the current value to one that may be safely measured by the ammeter. Usually, the instrument transformer is designed to reduce the full-load current to a secondary current of 5 amperes. In turn, the ammeter, which is connected to the transformer's secondary, is designed to produce a full-scale deflection with an input of 5 amperes. Since the ratio between the load current and the current in the instrument transformer secondary is practically constant, the ammeter scale can be calibrated to read a true value of load current. Now, in the example being used, the generator had a full-load current of 264 amperes when connected for a 220-volt output. That meant

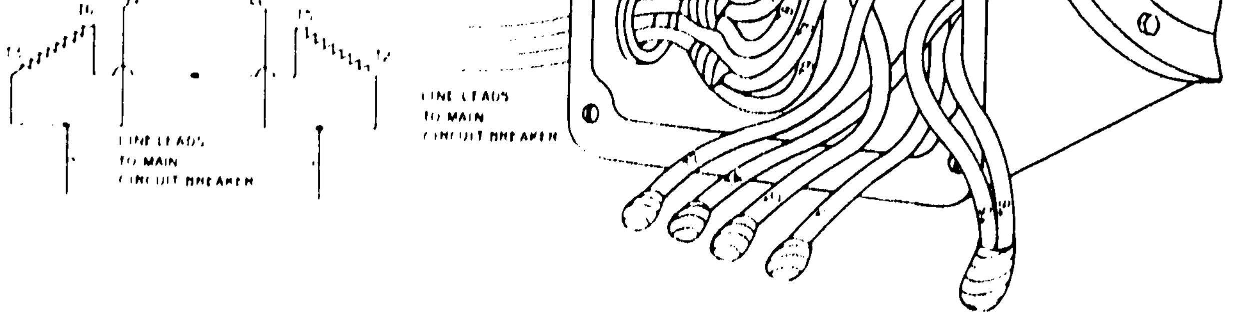

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Figure 9-26. 220-volt, single-phase connections.

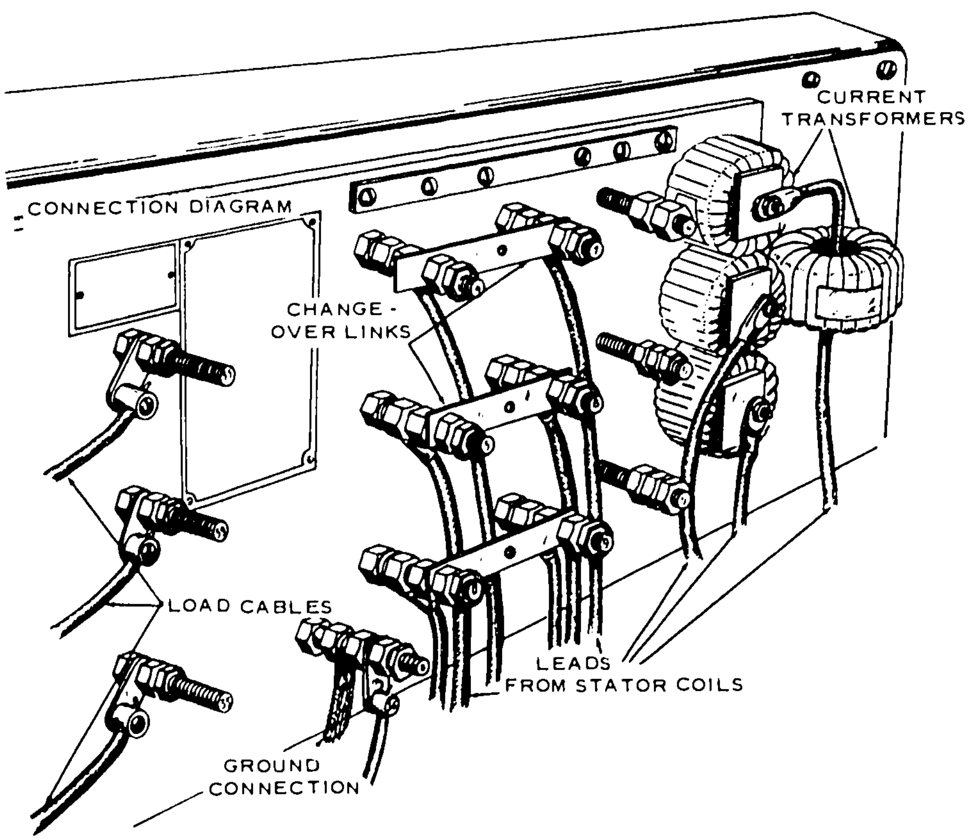

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Figure 9-26.—Representative changeover block showing generator and load connecting points.

that the instrument transformer induced 5 amperes of current in its full secondary winding when 264 amperes flowed in the line and, as a result, the ammeter had a full-scale deflection. On reconnecting the generator for 440 volts, however, you reduce the full-load current to 132 amperes. Unless you alter the instrument transformer connections, full-load current will produce a half-scale deflection of the ammeter which results in a false reading. In this case, you must move the instrument transformer winding connection from the full-winding position to the mid-tap position. However, most switchboard ammeters have another calibrated scale which makes it unnecessary to apply a correction constant when the current range is changed.

Another possible change in the generator's switchboard wiring concerns the voltage regulator, whose main purpose is to keep the generated voltage within certain limits regardless of changing load conditions. Although there are many types of voltage regulators they all respond to VARIATIONS IN RATED LINE VOLTAGE. However, the line voltage is not applied directly to the regulator unit. A potential transformer is used to reduce the line voltage to a standard value that is safe for the regulator. The ratio of primary voltage to secondary voltage must remain constant if the regulator is to function properly within the limits of the generator's rated voltage. Therefore, when the output voltage of the generator is changed, you must also change the tap connections on the primary of the potential transformer.

Now comes a likely question. To make these changes must you actually dive into the maze of wiring behind the generator's switchboard and move leads from one terminal to another? Generally no. In a few cases you may have to change the leads. Most manufacturers have provided a means to simplify the changeover from one voltage output to another.

One type of changeover device in advanced base generators is shown in figure 9-26. Called a CHANGEOVER BLOCK, it is mounted on the rear of the generator's switchboard (control cabinet). The terminal studs that protrude from the changeover block serve two purposes: they provide a disconnect point between the load cables and the generator coil leads, and they present a convenient means of altering the operating characteristics of the generator's components without changing the positions of the wires. Notice that each of the 10 generator stator coil leads is attached to a correspondingly numbered terminal stud. Rearrangement of the coil leads becomes a simple process of interconnecting the terminal studs in a definite pattern by the use of CHANGEOVER LINKS.

When in position on the coil lead terminal studs, the changeover links also contact other studs that are connected to components, such as the current transformers and the potential transformers. Thus, the outputs of these components are also changed automatically. Connection diagrams on a nameplate attached to the changeover block provide information on the positions of the changeover links for specific voltage outputs.

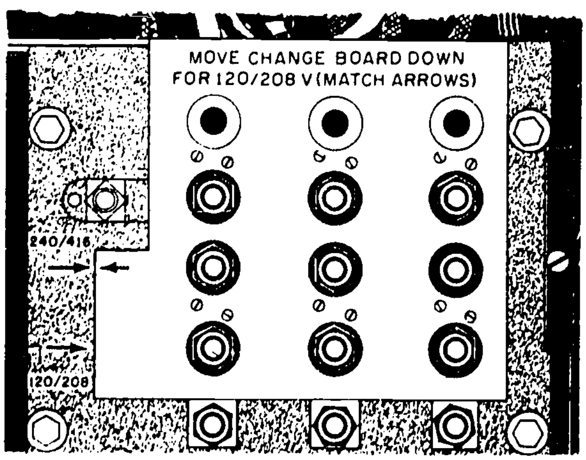

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Figure 9-27. — Reconnection panel.

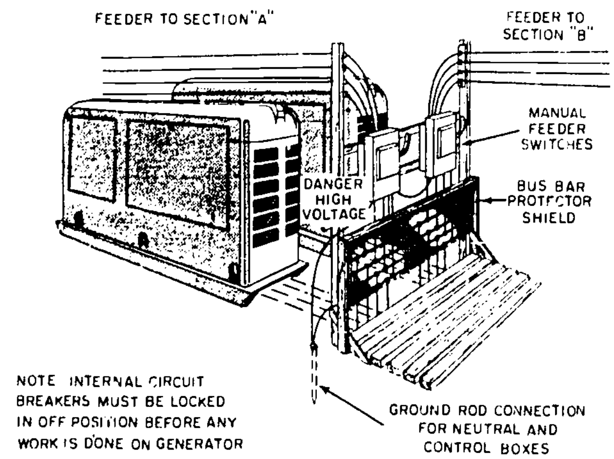

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Figure 9-28. — Representative bus bar installation.

A newer type of changeover board with its instructions is shown in figure 9-27.

Remember that you are responsible for the proper operation of the generating unit. Therefore proceed with caution on any reconnection job. Study the wiring diagrams of the plant and follow the manufacturer's instructions to the letter. Before you start the plant and throw the circuit breaker, double-check all connections.

BUS BAR

There are a number of reasons why sometimes you must use a bus bar when setting up a portable generating station. For one thing, you may not be able to get a generating plant that has sufficient capacity to meet the total power demand of the electrical load. In this case, then, use two or more generating units and collect their paralleled outputs at one central point (the bus bar). Or, you may discover that the electrical equipment in the advanced base is scattered in such a manner as to require the use of feeder (branch) lines that can be controlled from a central source. Again, the bus bar is the answer.

A representative advanced base generating station using a bus bar is shown in figure 9-28 (circuit breakers are enclosed in the generator). Be sure that disconnects are inserted in the installation as shown in figure 9-29. The two generators are leveled on a concrete pad that

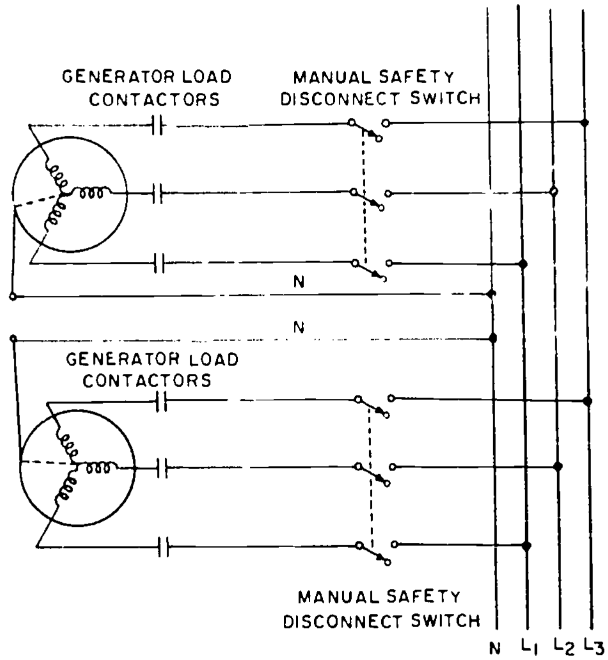

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Figure 9-29.—Schematic of bus bar installation.

is sloped for drainage. The electrical output of each generator is transferred underground to the bus bar by four single-conductor cables. The bus bar itself consists of four cables stretched between two 4- by 4-inch posts. A secondary rack mounted on each post serves as an insulating support for the bus bar cables. Two switches, one for each feeder line, are mounted above the bus bar. A wooden platform provides an insulating medium for operating personnel.

Whether or not the schematic of your bus bar installation looks exactly like figure 9-29, the point to remember is that the equipment should be properly secured and supported, and where necessary, properly insulated. The size of wire will depend on the load current. The switches that control the output to each feeder line can be either fused knife switches or circuit breakers. Be sure that the current rating of the fuses or trip elements will provide adequate protection against excessive overloads or short circuits on the feeder lines. Also that the switch blades or breaker contacts are capable of carrying the rated current and voltage of the feeder lines. In addition, protect the switchgear and bus bar from the weather by having a weatherproof canopy built over the rack. The canopy will help ensure uninterrupted service and protect operating personnel.

Improving Power Factor

From your study of basic electricity, you learned that power factor can be improved in parallel circuits by adding capacitors of the proper size in parallel with the load at the points where improvement is needed.

How much capacity to add will generally be figured out for you by someone in operations or the company office.

Generally the most effective location for installation of individual capacitors is as close to the inductive load as possible. This provides maximum power factor correction from the capacitor back to the source of power.

Capacitors should be installed where the temperature of the air does not exceed 104° (40° C). They should always be well ventilated because they always operate at full load and generate heat which must be removed.

Most power capacitors are provided with fuses which provide protection in case of an internal short circuit. An accepted method of wiring capacitors is illustrated in figure 9-30, where a separate service switch is used.

Capacitors can be mounted on the floor, wall or ceiling, depending on the floor space and equipment layout. Most come equipped with mounting brackets, so that they can easily fit into these places.

AN IMPORTANT SAFETY PRECAUTION IS THAT A 5 MINUTE WAITING PERIOD MUST BE OBSERVED BEFORE ANY WORK IS DONE ON A DISCONNECTED CAPACITOR. Since a disconnected capacitor may retain its electrical charge and have full line voltage across its terminals, these terminals must be short circuited and grounded before any work is begun.

PREPARING TO OPERATE THE GENERATOR SET

After setting up a portable generator set, you must do some preliminary work before placing it in operation.

INSPECTING THE GENERATOR

First make a visual overall inspection of the generator. Look for broken or loose electrical and hose connections, and for loose bolts

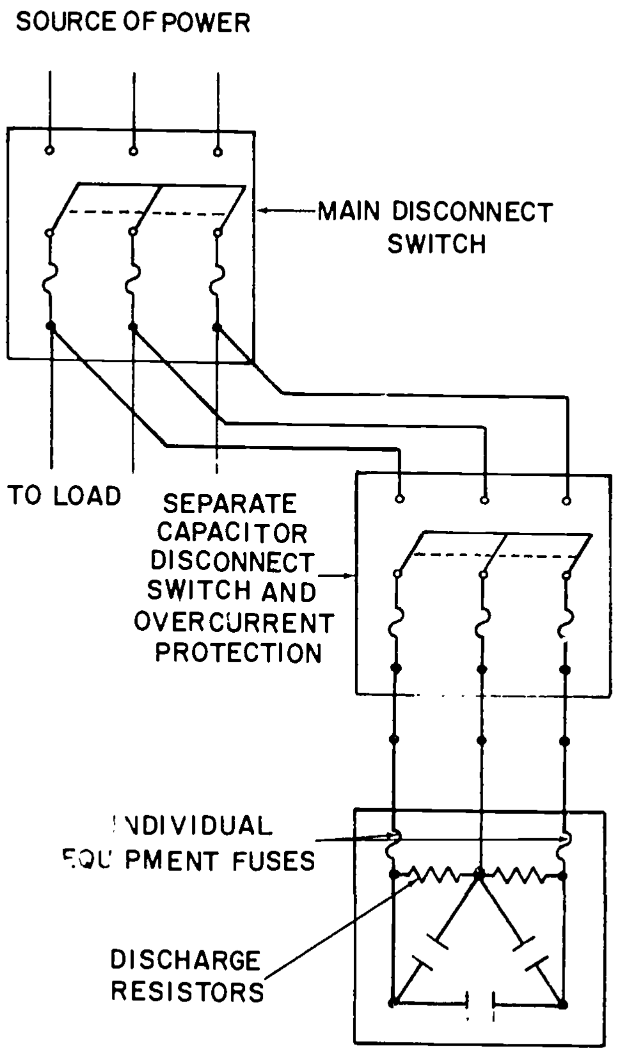

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Figure 9-30.—Capacitor installation with overcurrent protection.

and capscrews. See that the set is properly grounded. Check the wiring diagrams in the instruction manual furnished with the generator, to see if any wire connection is suspected of being improperly connected. Any faults that are found should be corrected immediately.

SERVICING THE PRIME MOVER

Servicing the prime mover is the next step in the process of placing the generator in operation. Be sure that the crankcase is filled with the proper grade of oil and lubricant. A lubrication chart in the instruction manual furnished with each generator will show the proper grade of oil to use at the operating temperature. Regardless of the air temperature, be sure to use an antifreeze solution in the proportions recommended in the instruction manual for the generator.

The fuel tank should be filled with clean fuel oil, strained if necessary.

Prime movers of advanced base electric power generators are started by starting units which obtain their power from batteries. If your prime mover is equipped with a battery (or batteries) you have another servicing job to do. Batteries are usually shipped without the electrolyte, but with the plates in a dry-charged condition. Thus, it is necessary to fill the battery with electrolyte. Usually, the electrolyte is shipped right with the generator and is of the correct specific gravity.

If you must prepare your own electrolyte, however, consult a mixing chart (table 9-3). In this case, use the specific gravity value recommended in the instruction manual.

CAUTION

BE SURE TO ADD THE ACID TO THE WATER S-L-O-W-L-Y, STIRRING CONSTANTLY AND THOROUGHLY.

Table 9-3.—Electrolyte Mixing Chart

SPECIFIC GRAVITY DESIRED	USING 1.835 SPECIFIC GRAVITY ACID		USING 1.400 SPECIFIC GRAVITY ACID	
	PARTS OF WATER	PARTS OF ACID	PARTS OF WATER	PARTS OF ACID
1.400	3	22	..	..
1.345	2	1	1	7
1.300	5	2	2	5
1.290	8	3	9	20
1.275	11	4	11	20
1.250	13	4	3	4
1.225	11	3	1	1
1.200	13	3	13	10

26.164

After the electrolyte has been prepared, again see the instruction manual for the recommended filling procedure. If the manual is not available, follow this general procedure: First, add electrolyte to each of the battery's cells until the level of the electrolyte is visible in the filler neck or at least 3/8 inch above the separators. The temperature of the electrolyte when placed in the cells should be between 60° and 90° F. IT SHOULD NEVER EXCEED 90° F.

Chemical reaction resulting from adding electrolyte will cause the battery to heat. Cool it artifically (cooling fans) or allow to stand at least 1 hour before placing it in service.

You will probably notice at the end of the cooling period that the level of the electrolyte has dropped due to the electrolyte soaking into the plates and separators. Before placing the battery in service restore the electrolyte to its proper level. Remove any electrolyte spilled on the battery, using a cloth dampened with a solution of bicarbonate of soda and water.

Although the battery can be placed in service 1 hour after filling it with electrolyte, do so only in an emergency. If at all possible, give the battery an initial light charge.

If the instruction manual is not available or if it does not give the battery charging procedure, proceed as follows:

Charge the battery at a low rate (about 5 amperes) until the voltage and specific gravity, corrected to 80° F, remains constant for at least 5 hours. If the temperature of the electrolyte reaches 125° F reduce the charging rate or stop the charge until the battery cools. NEVER PERMIT THE TEMPERATURE TO EXCEED 1[illegible]° F. During charging, replenish any [illegible] loss by evaporation.

After the battery has been charged, connect it into the starting system of the prime mover as indicated by the wiring diagrams accompanying the generator.

On large generators you should check the area ventilation; the fan cover must be opened and latched in that position. There must be no cover or obstructions over the main diesel engine exhaust stacks, or over the radiator section. The bypass shutters or doors may be closed to shorten the warming-up period, and roof hatches and side louvers MAY be opened for additional ventilation, if required.

SERVICING THE GENERATOR

Just as important as the preparation of the prime mover is the inspection and servicing of the alternator. Generally, you should take the following steps:

1. Find all the electrical connections by referring to the generator's connection diagrams and see that the connections are tight.

2. See that the collector rings are clean and have a polished surface.

3. Check collector brushes to make sure they have no tendency to stick in the brush holders, that they are properly located, and that the pigtails will not interfere with the brush rigging.

4. Check the collector brush pressure, making sure it agrees with the pressure recommended in the manufacturer's instruction manual. Calculations for brush pressure may be made, using a spring scale (to measure the spring tension) and the formula:

$$\frac{\text{Pressure (psi).}}{} = \frac{\text{Tension (in pounds)}}{\text{Brush width x Thickness (inches).}}$$

Example:

Manufacturer's recommended tension	= 40 ounces (2.5 pounds)
Brush width	= 1/2 inch
Brush thickness	= 1-1/8 inch

Substituting those figures in the formula above,

$$\text{Pressure} = \frac{2.5 \text{ pounds}}{0.5 \times 1.125} = 4.4 \text{ psi}$$

SERVICING AND OPERATING PROCEDURES

You must always check the appropriate instruction manual for specific operating and servicing procedures. The following information, however, is general and applicable to the generators you may encounter.

Make sure that the fuel you are going to use is not contaminated with dirt or water, and that all equipment (cans, funnels, and/or nozzles) for transferring the fuel to the engine fuel tank is clean. Dirty fuel clogs the carburetor and fuel lines.

Water in the fuel often keeps an engine from starting and damages the injection pumps and nozzles of diesels. In cold weather, especially,

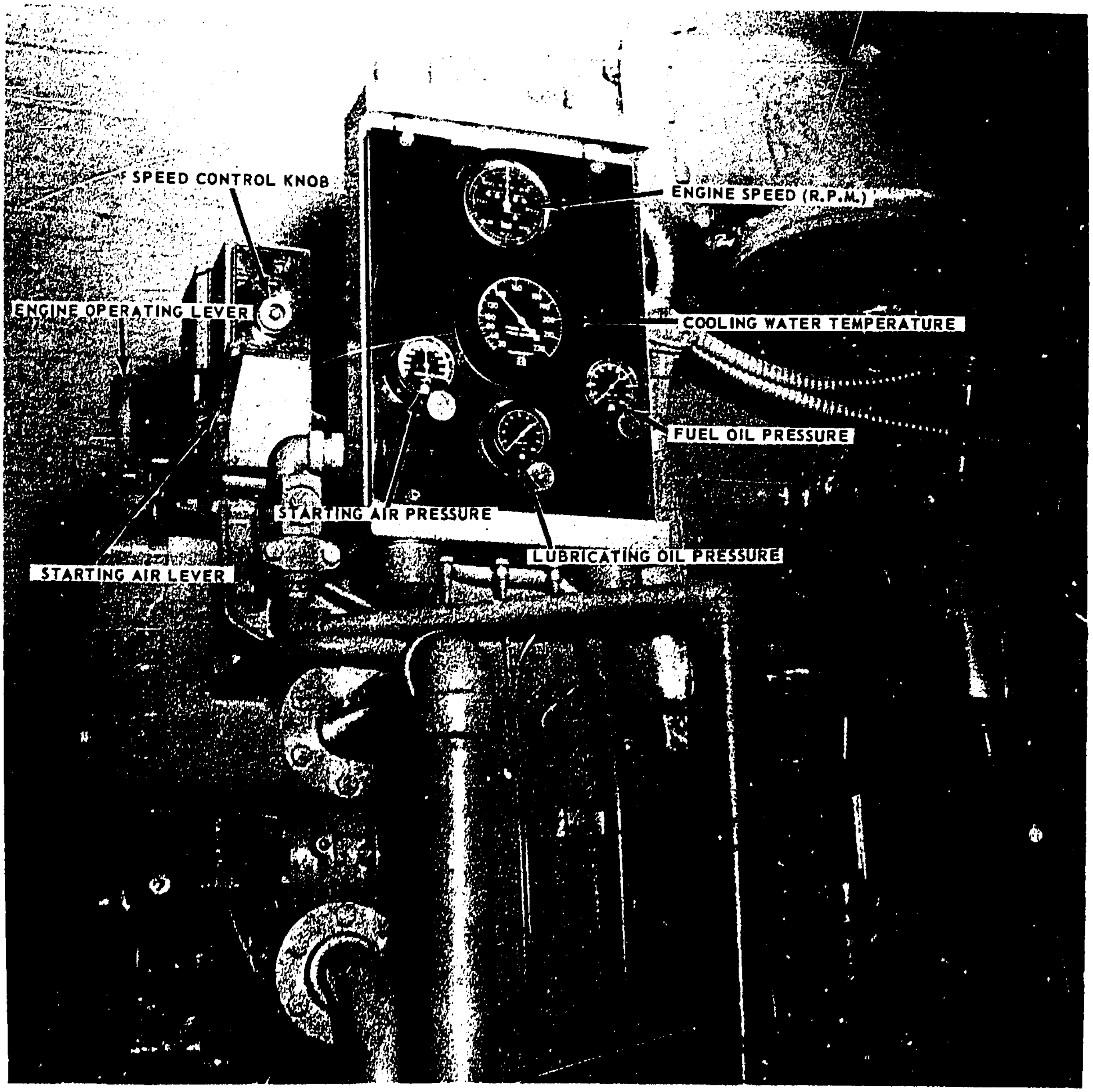

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Figure 9-31. — Diesel engine, showing controls and gages.

fuel tanks should be kept full to minimize condensation of moisture in them.

BE SURE THE FUNNEL IS IN DIRECT CONTACT WITH THE TANK when fuel is being transferred, to eliminate the possibility of an explosion.

Damage due to dirt can be eliminated or minimized by changing the air cleaner at appropriate intervals. If the oil feels gritty when checking its level, change it and the filter too.

If your generator set requires water for its cooling system, be sure to keep it filled. Remember, that in freezing temperatures, antifreeze must be added.

Check the battery electrolyte level periodically and add water if required. When available, distilled water is preferable to plain water. Coat the battery terminals with a light coating of corrosion-preventive grease after connections have been tightened.

OPERATION OF POWER STATION

Once the central power station has been established, the various base activities should be able to count on a continuous and adequate flow of electric current to supply the needs of the living and working spaces. As a Construction Electrician who has worked on the installation of the power distribution system, you will have a good overall working knowledge of this system. However, you should also know how to operate and maintain the equipment in the power generating station.

You can help yourself to the required know-how by studying the general operating and maintenance procedures in this chapter, by referring to electrical plans and diagrams relating to tasks involved, and by consulting the instruction manual furnished with each piece of plant equipment.

STARTING AN A-C GENERATOR

The following description of the steps in starting an a-c generator is a general description only. For a particular generator you follow the step-by-step instructions for starting given in the manufacturer's manual.

It is assumed that the generator is driven by a diesel engine which is started by air pressure (some diesels are started by an electric starting motor and batteries or by a gasoline engine which is cut off after the diesel engine starts running on its own fuel).

Figure 9-31 shows the controls and gages of a diesel engine that drives a large generator. The STARTING AIR LEVER controls a valve which admits starting compressed air to the engine cylinders. The ENGINE OPERATING LEVER controls engine speed while starting, stopping, or in an emergency. The SPEED CONTROL KNOB controls engine speed during normal operation. Figure 9-32 shows details of the engine operating lever.

The speed control lever controls engine speed during normal operation through a governor. In starting, the governor is made inoperative so that the operator can control engine speed during starting by manipulating the engine operating lever. To render the governor inoperative, you set the PAWL-ACTUATING LEVER (fig. 9-32) in the position where it points away from the engine. After the diesel engine starts, you turn the pawl-actuating lever toward the engine.

Before you start the diesel engine, see that the circuit breaker and the field switch on the

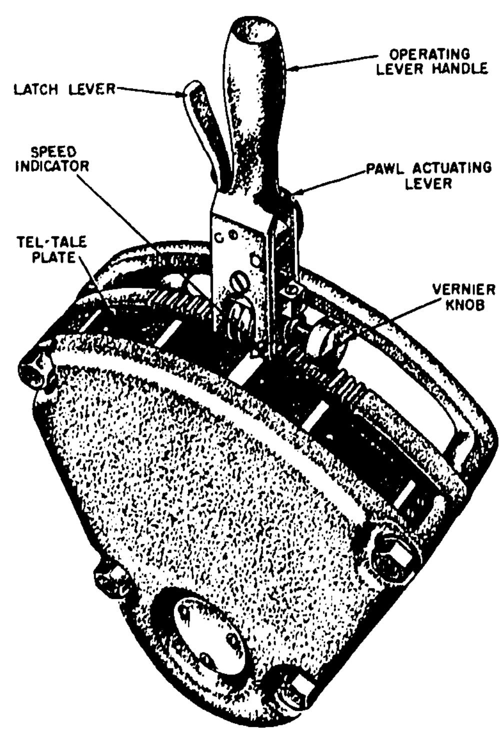

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Figure 9-32. — View of diesel engine operating lever, showing details.

generator switchboard are in the OFF position. This step ensures that no load exists on the generator. Next, set the pawl-actuating lever for manual control (away from the engine), and latch the engine-operating lever in the INJ FULL position (fig. 9-32).

The LATCH LEVER shown in figure 9-32 releases (by squeezing) the engine-operating lever for movement to a different position, and locks the same in the new position when the latch lever is released.

The VERNIER KNOB of figure 9-32 is used to control speed adjustment when you are operating the engine under manual speed control, as in an emergency.

Pull down on the starting air lever (fig. 9-31). This will admit air to the cylinders, which will in turn set the pistons in motion. The engine should fire within 10 seconds; when it does, release the starting air lever.

Immediately after the engine fires, check the LUBRICATING OIL PRESSURE GAGE (fig. 9-31). If it does not indicate oil pressure within 10 seconds after the engine fires, stop the engine at once by moving the engine-operating lever to the INJ STOP position (fig. 9-32).

If lubricating oil pressure is satisfactory, turn the pawl-actuating lever toward the engine and move the engine-operating lever to the GOV RUN position. Engine speed is now controlled by the governor.

Make sure you know the engine speed required to maintain the required voltage output. Assume that to produce a 60-hertz voltage, the engine must make 600 rpm. Check the rpm indicator and if it does not read 600 rpm, turn the SPEED CONTROL KNOB in the appropriate direction until the engine speed indicator reads 600 rpm.

Recheck the lubricating oil gage for proper oil pressure; also check the FUEL OIL PRESSURE GAGE for proper fuel oil pressure, and the COOLING WATER TEMPERATURE gage for proper water temperature (fig. 9-31).

PLACING GENERATOR ON THE LINE

Your generator is now running, but it is not yet "on the line", that is, not delivering power to the distribution system. Before you set about putting the generator on the line, make sure that you know the locations of the various switchboard controls, and that you are able to operate them smoothly and in proper sequence; check to see that the voltage regulator switch is in OFF (or MANUAL CONTROL) position, and that the voltmeter selector switch is set to permit the a-c voltmeter to indicate the desired measurement.

Turn the handle of the exciter field rheostat counterclockwise as far as it will go, so as to put maximum resistance into the shunt field of the exciter.

Throw the field switch to the ON position, thus making exciter voltage available to the generator field. At the same time watch the a-c voltmeter and ensure that it records a low reading.

Turn the exciter field rheostat knob clockwise, thus decreasing exciter field resistance, and increasing exciter field voltage and excitation current in the generator's field winding. This will cause output voltage to rise. Watch the a-c voltage meter, and turn the rheostat knob until the rated voltage is reached.

Check the frequency reading on the frequency meter. Increase or decrease the engine speed until you read normal frequency (in this case, 60 hertz).

Turn the voltage regulator switch to the ON or AUTOMATIC position, thus placing the voltage regulator in control. Then check the voltmeter to ensure that it still reads rated voltage value. If the value has changed, adjust the voltage regulator rheostat until the voltmeter again reads rated value.

Release the interlock on the circuit breaker, thus closing the generator circuit and energizing the bus. With the generator now connected to the external circuit, the a-c ammeter will indicate the current drawn by the load.

Check the current in each phase by switching the ammeter. Recheck the voltage across each phase.

SYNCHRONIZING GENERATORS

The load power demand may often reach a point where it cannot be satisfied by a single generator. In this case, it becomes necessary to "cut in" or "parallel" another generator—that is, add another generator to the bus. You CANNOT parallel by simply starting the engine of a reserve generator and place this generator on the line by throwing the main switch. You must go through a procedure that concerns four important events: (1) The incoming generator voltage must equal the bus voltage. (2) It must have the same frequency and (3) must be in phase with the bus voltage. (4) All phases must be connected in proper sequence. This procedure is called synchronizing or paralleling generators.

To adjust frequency,—you adjust the speed in rpm of the prime mover—thereby ensuring that the difference in potential between CORRESPONDING terminals of the two generators is zero. Watch the voltmeters on the two units until they read the same. To bring the incoming generator into phase with the voltage on the bus, you will either use a lamp method or a synchroscope of synchronizing lamps. In paralleling generators, you will either use a lamp method or a synchroscope.

Lamp Synchronizing Methods

The most satisfactory method of synchronizing generators, using lamps, is the two-bright one-dark method of figure 9-33. Note that the lamps are connected directly between the incoming generator's output and the buses.

In this way, the two a-c sources may be synchronized before the incoming generator's main power contactor is closed. At the instant the two generators are to be paralleled, L_2 and L_3 will glow with maximum brilliance and L_1 will be dark.

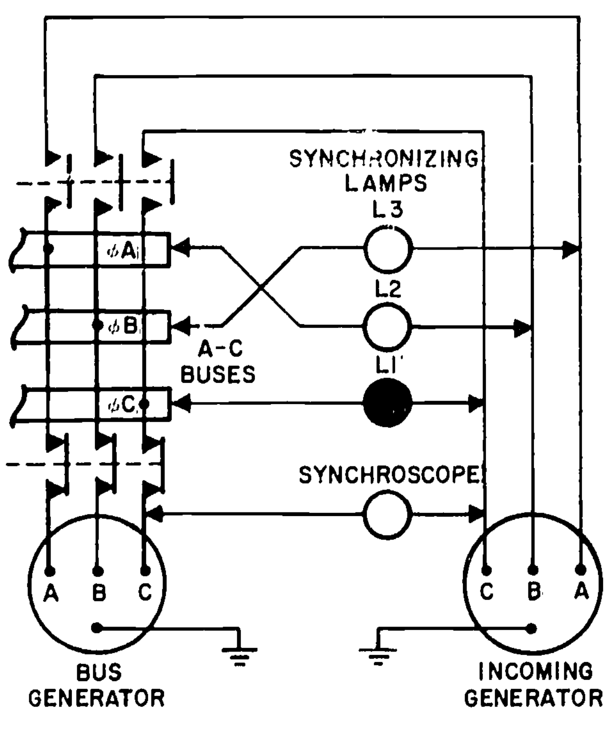

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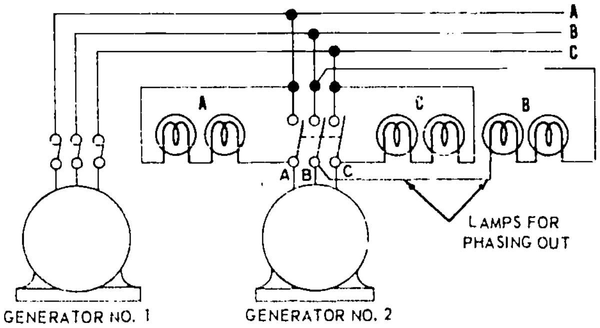
Figure 9-33.—Synchronizing lamp connection for two-bright one-dark method.

Assume that the incoming generator is far out of synchronism—lagging. All three lamps will appear to glow steadily, because the frequency of the voltage across them is the difference in the frequencies of the two generators, and thus is too high for individual alterations to be observed. As the lagging generator is accelerated, however, the lamp (differential) frequency decreases until their light flickers visibly. Their flickering will have a rotating sequence, if connections are correct, and will indicate which generator is faster.

At a point approaching synchronism, lamp L_1 will be dark because it is connected between like phases. That is, the two phase C voltages will be so nearly synchronized that their differential voltage across L_1 will be insufficient to make it glow visibly. However, this differential may still be of sufficient magnitude to damage the generators should they be connected at this time. The reason for cross-connecting L_2 and L_3 is now indicated. Under perfectly synchronized conditions, the phase voltages across L_2 and L_3 are both 120° apart, because of their cross-connection, and both glow with equal brilliance. However, if the generators are not in complete synchronism, but only very near it, one of the bright lamps would be increasing in voltage as the other was decreasing. This action would cause a visible difference in the brilliance of L_2 and L_3. Thus, by adjusting the incoming generator's frequency so that no visible difference of brilliance exists between L_2 and L_3, the exact point of synchronism can be approached very closely before paralleling the incoming generator with the generator on the bus.

Two other methods are used, one is called the "all-dark" method, the other, the "bright-lamp" method.

In the all-dark method of synchronizing, lamps are connected across an open three-pole switch between the bus and the incoming generator as shown in figure 9-34. If the lamps increase and decrease in brilliance together, the phase sequences of the two generators are the same. If the lamps rotate in brilliance, the phase sequences are not identical. Interchanging any two of the three leads from the incoming generator will obtain the correct phase sequence. Be sure the lamps have a voltage rating twice the generator terminal voltage. If lamps of this voltage rating are unavailable, several lamps in



73.60
Figure 9-34.—The all-dark synchronizing method.

series, voltage dropping resistors, or stepdown transformers must be used. When the lamps are dark the voltages are in phase and the paralleling breaker may be closed.

The "bright-lamp" method is more sensitive and is used for large, high-speed generators. The arrangement of lamps is shown in figure 9-35. When lamps A and C burn with the same brilliancy the unit is in phase. As one of the two increases in brilliancy and the other decreases, the instant of synchronism is the instant when they match in brilliancy. The sequence of brightness of the lamps indicates whether the incoming alternator is fast or slow. It is standard practice to close the generator breaker when the incoming alternator's frequency is slightly ahead of that of the already operating alternator.

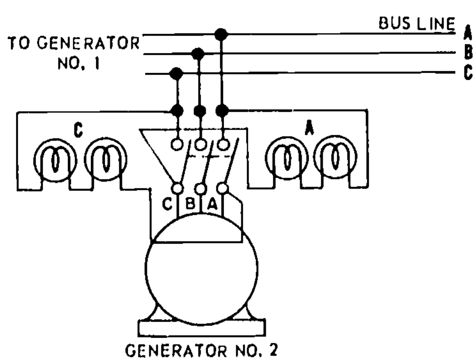


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Figure 9-35.—The bright lamp synchronizing method.

Synchronizing With Synchroscope

The sequence of operations in paralleling two alternators by synchroscope follows.

Compare the bus voltmeter reading (voltage produced by the already operating generator) with that on the incoming generator voltmeter. If the readings are not the same, adjust the voltage regulator rheostat of the incoming generator until its voltage is equal to the bus voltage. This is an important step, because unequal voltages will cause circulating currents to flow between the parallel generators.

Compare the frequency of the incoming generator with that of the bus, and adjust to correspond by means of the incoming generator's governor motor-control switch.

Turn the synchronizing switch to the ON position. The synchroscope will rotate in one direction or the other. (If the switchboard is also equipped with synchronizing lamps, they will increase and decrease in brilliancy.)

Use the governor motor control switch to adjust the speed of the incoming generator until it is operating at approximately the same frequency as the bus voltage. This will be indicated by the synchroscope rotating slowly in the FAST direction. (The synchronizing lamps will slowly increase and decrease in brilliancy.)

Make sure the voltages of bus and incoming generator are the same. Then, JUST BEFORE the synchroscope pointer passes through the zero position, close the incoming generator's breaker and thus "cut in" the generator.

After the incoming generator has been thus "cut in" to the bus, there are two additional adjustments that must be made. One of these ensures that each generator is carrying its share of the kilowatt load. The other ensures that each generator is operating with the same power factor.

The division of kilowatt load between a-c generators operating in parallel depends on the relative setting of their engine governors. Equalizing power factor means ensuring that each generator is producing its share of wattless current or "reactive kva." The amount of reactive kva two generators supply depends on the relative setting of their voltage regulators. Therefore, to adjust the generators for parallel operation you take the following steps.

Turn the governor motor control switches until the wattmeters of the generators read the same (if the generators have the same rating), or until the load is proportionally divided (if the generators have different ratings). The load is increased on a too lightly loaded generator by increasing engine speed, on a too heavily loaded generator by decreasing engine speeds. These adjustments must be made simultaneously, to maintain constant frequency.

To balance reactive load, turn the voltage regulator rheostat of each generator until the power factor meter reading is the same for each, indicating that the burden of reactive kva is being properly shared. If the switchboard is not equipped with power factor meters, the a-c ammeter of each generator can be used. Proper adjustment exists when the ammeters show equal currents for generators of the same rating, or proportionally equal currents for those of different ratings.

The direction in which you turn the voltage regulator rheostat of each generator depends on the reading of the generator's power factor meter or ammeter before the adjustment is made. The voltage should be decreased on the generator carrying too much power factor, increased on the one carrying too little.

After closing the main breaker, observe the a-c ammeters of equal generating units to ensure that they read the same. Unequal readings mean that one generator is doing more work than the other. You can even out the load by increasing the speed of the generator having the lower ammeter reading. Adjust the control governor motor until both a-c ammeters read the same.

SECURING GENERATORS

When a SINGLE generator, connected alone to a bus, is to be taken out of operation, proceed as follows:

- Remove as many individual loads as possible to reduce arcing and damage to the line switch or circuit breakers when the circuit is opened. Open the feeder breakers to further reduce the generator load as much as practicable.

- Trip the generator circuit breaker.

- Turn the voltage regulator switch to the OFF or MANUAL position.

- Turn the handle of the exciter field rheostat counterclockwise, as far as it will go, thus cutting in all resistance to the exciter field and decreasing the voltage to the exciter field.

CAUTION: The field circuit of a generator which is to be disconnected from the bus bars must not be opened before the main breaker has been opened. If the field circuit is opened first, a heavy current will flow between the armatures.

- Move the governor control lever to the low idle engine speed and run the engine about 5 minutes until it cools down.

- Stop the prime mover by moving the engine operating lever to the GOV STOP position (fig. 9-32).

It may be necessary to secure a generator which is operating in parallel with another. The typical situation is one where a peak load (as when darkness falls and many lights come on) occurs and then passes. When the load comes on, another generator is cut in; when it passes, the generator is secured.

Before you remove the generator power from the bus, it is very important that you shift the kilowatt load being carried by the generator which will be cut out to the generator or generators which will remain on the line. This shift of kilowatt load is accomplished by turning the governor motor control switch of the generator to be secured to LOWER, and the same switches on the remaining generators to RAISE. The wattmeters on the switchboard will indicate how the shift is progressing and when it is completed.

When the load has been shifted, trip the circuit breaker on the generator which is to be taken out, and then secure that one as you would a single generator.

A generator which has been operating under a heavy load should not be shut down until it has been run on a light load for a few minutes to reduce temperatures.

EMERGENCY SHUTDOWN

In the event of engine overspeed, high jacket water temperature, or low lubricating oil pressure, the engine may be shut down and disconnected from the main load by tripping the main circuit breaker. In addition, an indicator may light or an alarm will sound to indicate the cause of shutdown. After an emergency shutdown and before the engine is returned to operation, the cause of shutdown should be investigated and corrected. NOTE: It is important to check the safety controls at regular intervals to determine that they are in good working order.

OPERATING RULES

The orders posted in the station for the guidance of the watchstanders should include a general list of operating rules and electrical safety precautions. MAKE SURE YOU CARRY THEM OUT! Here are a few simple, but important, operating rules.

Watch the switchboard instruments. They show how the system is operating, reveal overloads, improper division of kilowatt load or of reactive current between generators operating in parallel, and other abnormal operating conditions.

Keep the frequency and voltage at their correct values. A variation from either will affect, to some extent at least, the operation of the base's electrical equipment, especially teletypewriters and electric clocks.

USE GOOD JUDGMENT WHEN RECLOSING CIRCUIT BREAKERS AFTER THEY HAVE TRIPPED AUTOMATICALLY. Generally the cause should be investigated if the circuit breaker trips immediately after the first reclosure. However, reclosing the breaker a second time may be warranted if power has to be restored immediately. Don't forget, repeated closing and automatic tripping may damage the circuit breaker and thus increase the repair or replacement work.

Don't start a plant unless all its switches and breakers are open and all external resistance is in the exciter field circuit.

Don't operate generators at continuous overload. Record the magnitude and duration of the overload in the log; record any unusual conditions or temperatures observed. Readings taken over a period of time may show a trend, such as decreasing oil pressures or increasing engine temperatures, that points to a trouble or fault.

Don't continue to operate a vibrating machine. Find and correct the cause; then record the cause in the log.

GENERATOR WATCH

Constant, around-the-clock attention must be given to the generators at a central power station that is required to supply a continuous and adequate amount of power. The 24-hour period is divided into a number of watches: the number depends, of course, upon the personnel available for this type of duty.

At most stations, 6-hour watches are the common practice. An 8-hour watch schedule does not ordinarily work a hardship, but watches of more than 8 hours should be avoided except in an emergency.

Besides operating the generating equipment, watchstanders must keep the daily operating log, do housekeeping chores, and the generating equipment.

Keeping a Station Log

A station log is a written record which serves a number of purposes. For one thing, it indicates when various equipment units require periodical maintenance work or replacement. A series of entries can often pinpoint signs of breakdown when the breakdown occurs so gradually that it never becomes an obvious problem at any particular instant.

With a great many items of complex equipment working together to produce heat, light, and power for an entire base, it is vital that each item of this equipment be kept operating satisfactorily. A well-kept log is an important means for alerting a trained man to the first signs of trouble.

The form used for log entries varies with the views of the supervisory personnel in different plants, and there is no standard form to be followed by all stations. Regardless of form, any log must describe the hourly performance, not only of the generators, but also of the numerous indicating and controlling devices.

Figure 9-36 shows one type of log that may be kept on the generator units of a power plant. This is only a suggested form, of course, and there may be at your station many other items to keep a record on.

Housekeeping

As a watchstander keep your duty station clean and orderly. Also keep in their proper places tools and auxiliary equipment that are not being used. Store clean waste and oily waste in separate containers. OILY WASTE CONTAINERS MUST BE KEPT COVERED. Empty oily waste containers at least once a day to reduce fire hazards. Care given the station floor will depend on its composition. Generally,

SUGGESTED FORM OF PLANT OPERATION LOG

Date	Time	UNIT NO 1785			UNIT NO 942			UNIT NO 3465			REMARKS
		Elapsed Time Meter	Volts	Amperes	Elapsed Time Meter	Volts	Amperes	Elapsed Time Meter	Volts	Amperes	
4/17/70	1600	1950	220	58	302.0	220	52	9340	220	27	Started up
"	1730	1965									added 2 qts oil to #1785
"	2100	2000	221	54	3070	221	49				Shut down #3465

OPERATOR ____________

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Figure 9-36. — Representative generating station operator log.

it should be swept down each watch. Remove at once any oil or grease that is tracked around the floor.

Operator Maintenance

Since there are many different types of generators, you should consult the manufacturer's instruction manual for details concerning maintenance of your equipment. SAVE THIS INSTRUCTION MANUAL! Additional copies are rarely available.

The lubrication and maintenance schedule taken from an instruction manual follows:

1. Grease fuel transfer pump every three months.
2. Grease generator yearly with Mil-G-10924 grease.
3. Change oil in air cleaner every 50 hours of operation. Oil in oil bath air cleaner should be changed every time the oil is changed in the engine crankcase. The oil level of the air oil bath filter should be checked daily. Operation of the unit in extreme dust conditions necessitates more frequent maintenance on oil bath air filters.
4. Grease water pump belt tightener idler pulley.
5. Replace brushes if less than 1/4" long.
6. Every three months, clean load contactor faces (do not file); check all connections for tightness and wipe magnet faces clean.
7. Inspect pole shader every three months and replace if cracked or broken.
8. Set battery charger timing relay to 24 hour position monthly.
9. Renew element and reassemble oil filters every 50 hours of operation.
10. Drain and refill engine crankcase with MIL-L-9000 lube oil every 50 hours of operation.

Observe all safety precautions. Safety warnings, such as keeping the funnel in contact with the fuel tank when filling with gasoline, might save a life. Here are some general daily maintenance and routine practices.

- Check the following:
  - Level of coolant
  - Radiator and coolant hoses for leaks
  - Battery electrolyte level
  - Fuel tank for leaks
  - Free movement of radiator shutters
  - All switches for proper operation

- Bring oil level to high mark on dipstick.

- Drain water and sediment from strainers.

- Drain water from fuel tank.

- Fill fuel tank as required with appropriate diesel fuel.

- Connect battery charger to utility source if unit is not operating.

The use of daily, weekly, monthly, and other periodic inspections and preventive maintenance programs rigorously enforced will minimize down-times of your equipment and help keep your equipment operational for longer periods of time.

SWITCHGEAR MAINTENANCE

At least once a year, a check should be made of the switchgear component, with careful attention given to the following factors.

General cleaning of the component parts is essential. The front panels of dead-front switchboards can be wiped off with a dry cloth. A metal-covered switchgear can be opened and inspected for surface cleanliness. Before any work is done on live parts, however, deenergize the switchboard. Wipe all dust from bus bars and insulating material.

Inspect electrical connections and mechanical fastenings. Do not limit this check to a sight inspection, but touch and shake the various parts to make sure that all connections are tight, and all mechanical parts free to function properly. Pay special attention to the bolted joints of the bus bar, because a loose joint can cause overheating.

Examine all meters and instruments mounted on the switchgear panels. Look for cracked or broken glass, or signs of damage to the cases. Adjust the pointer of each instrucment, so that it reads zero when the instrument is not energized.

Examine all indicating lamps, to make sure that none are burned out.

Inspect all instrument transformers mounted on the switchboard. To be in good condition, an instrument transformer must have all primary and secondary connections tight, and all grounding connections intact. Potential transformer fuses must make firm contact in their clips.

Check the condition of all rheostat mechanisms. Replace broken or burned-out resistors. If no replacements are available, make temporary repairs by bridging the burned-out sections. Check to see that there is nothing to block the ventilation of rheostats and resistors.

Test the operation of switchgear position-changing mechanisms, such as the lowering and raising mechanisms, and the pullout devices of the circuit breakers used in metal-clad switchgear.

SAFETY DEVICES AND INDICATORS

Many generator sets are equipped with various safety devices to protect the equipment from damage. These include low lube oil pressure, high coolant temperature, overspeed, overcurrent and reverse current, undervoltage and overvoltage relays. When a fault occurs, the generator is usually caused to shut down by appropriate automatic switches. Additionally, indicator lights come on making diagnosis of the cause of the fault easier. For example, when the oil pressure gage falls below 10 psi (pounds per square inch) in one generator, the main contactor opens to shut the engine off, and the low lube oil pressure indicator bulb lights up. Take advantage of the help provided by these indicators. Train yourself to identify the various indicators on the generator equipment. Ask yourself what would be wrong if such and such an indication is observed and what measures would you take to correct the fault.

It helps to become familiar with wiring diagrams, such as in figure 9-37 and to learn the physical locations of the components. Doing so will enable you to find and to troubleshoot them faster in an emergency.

Station personnel must observe all electrical safety precautions. Every electrical circuit, including those as low as 35 volts, is a potential source of danger. Never work on an energized circuit except in an emergency. In such a case, insulate yourself from ground by covering any

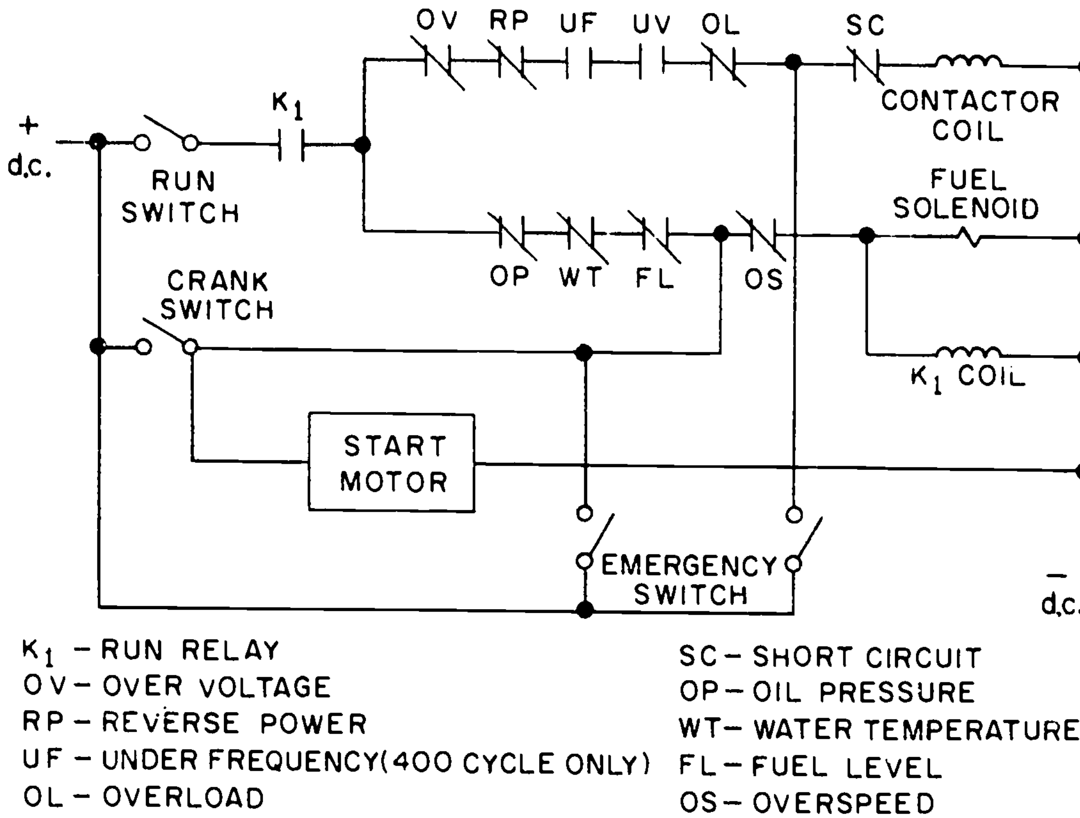

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Figure 9-37.—Practical wiring diagram of a representative safety control system for portable generator sets.

adjacent grounded metal with insulating material, such as dry wood, rubber mats, dry canvas, or serveral thicknesses of heavy dry paper. Also, provide enough lighting, cover metal tools with insulating rubber, and wear rubber gloves. Always station men at appropriate circuit breakers or switches so that the switchboard can be deenergized immediately and have available a man qualified to render first aid for electric shock.

TROUBLESHOOTING

Component parts found in most SRCR controlled regulators are power rectifier, silicon controlled rectifier, full wave rectifier, saturable reactor, and choke.

The troubleshooting information that follows will enable you to check out each of these components. You will find the manufacturer's book the most reliable way to check out the entire system. Always check with the manufacturer's book when troubleshooting, ordering and replacing parts.

POWER RECTIFIER

A power rectifier (diodes) is used to change a-c to d-c. The power rectifier of figure 9-38 can be compared to a hydraulic check valve in that it only allows current to flow in one direction (the direction of the schematic arrow). Its characteristics are such that it has a high resistance in one direction and a low resistance in the other direction. Failures occur due to four reasons:

1. Excessive current - causes overheating.

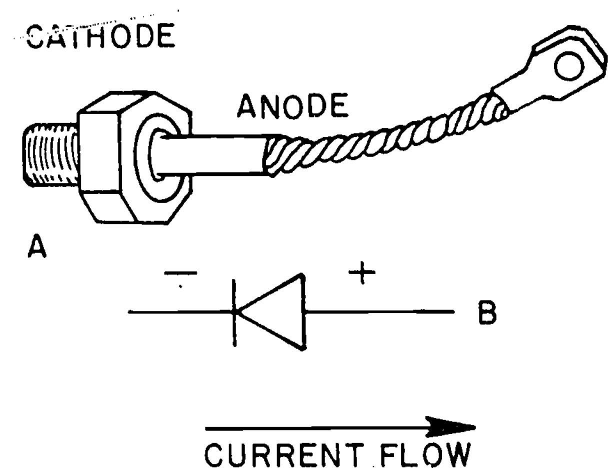

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Figure 9-38.—Power rectifier.

2. Excessive voltage - electrically damages the rectifiers interior parts.

3. Too much torque when replacing diode—physically damages the rectifier's interior parts.

4. Lack of silicon lubricant—causes rectifier overheating due to no transfer of heat from the rectifier to the heat sink.

A power rectifier can be checked with an ohmmeter. Its resistance should be over 100 times higher in one direction than in the other (1,000 times higher on the silicon type).

Silicon Controlled Rectifier

A silicon controlled rectifier (SCR) in figure 9-39, controls the amount of d-c that flows. It allows current to flow in one direction as a

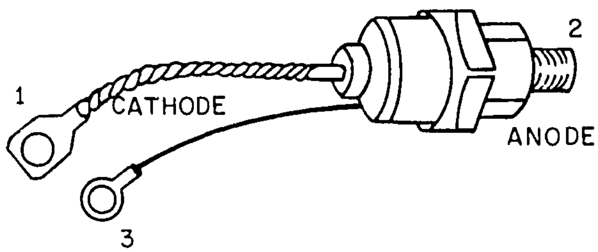

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Figure 9-39.—Silicon controlled rectifier.

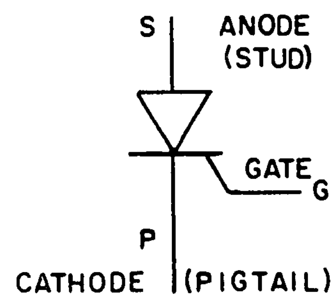

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Figure 9-40.—Cathode (pigtail).

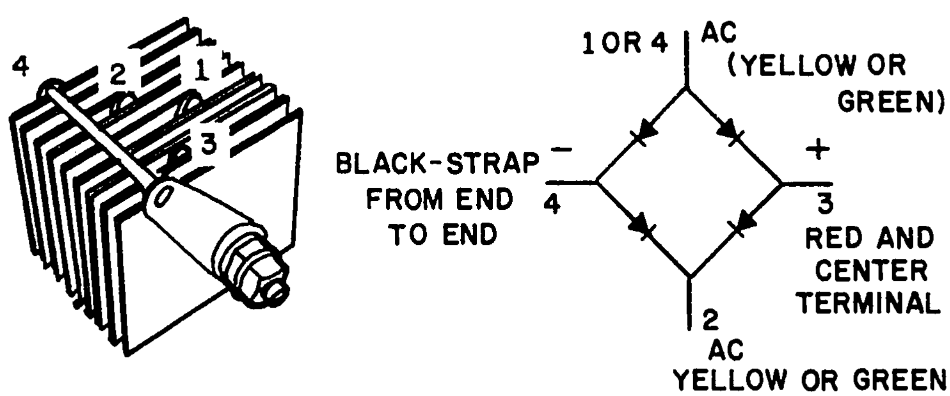

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Figure 9-41.—Full-wave rectifier.

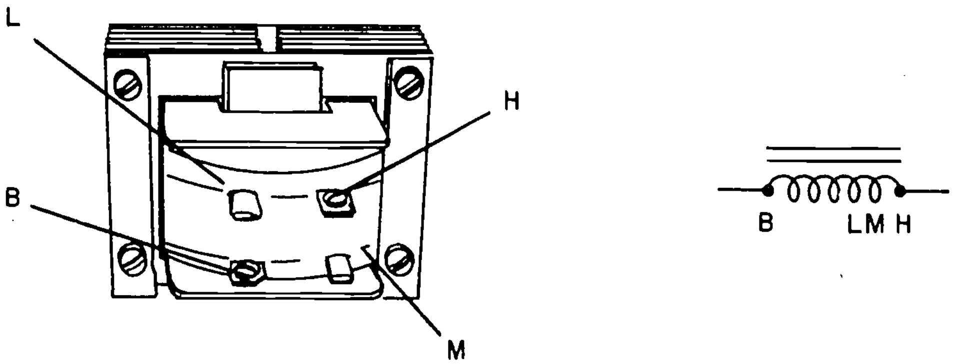

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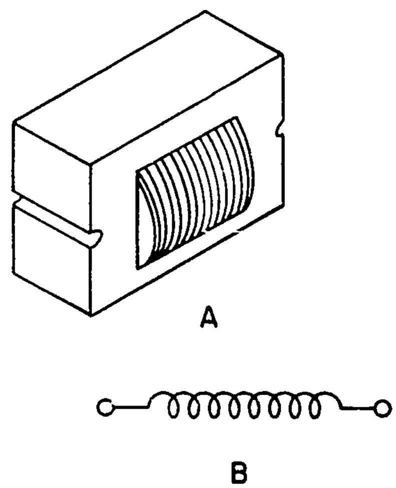
Figure 9-42.—Saturable reactor.

Table 9-4.—Rectifier check out

+1	-2	Reading high
	-3	Reading low
	-4	Reading high
+2	-1	Reading high
	-3	Reading low
	-4	Reading high
+3	-1	Reading high
	-2	Reading high
	-4	Reading high
+4	-1	Reading low
	-2	Reading low
	-3	Reading low



73.349

Figure 9-43.—Choke.

power rectifier does but only when a small positive voltage is applied to its gate terminal by some external means. When no positive voltage is applied to its gate terminal, the current will not flow through it.

A silicon controlled rectifier can be checked out with an ohmmeter. Readings across the terminals (fig. 9-40) should be as follows: terminals S-P, high ohms value; terminals S-G, high ohms value; and terminals P-G, 10 to 250 ohms.

Full-wave Rectifier

A full-wave rectifier (fig. 9-41) is used to change a-c to d-c. Consisting of four diodes arranged as shown in the figure, it fully rectifies a-c to d-c to allow full current flow; a single rectifier or diode allows only half of the a-c to flow.

It can be checked with an ohmmeter by placing the positive and negative ohmmeter leads as follows using table 9-4 as a guide: Place positive test lead on No. 1 terminal and negative test lead on No. 2 terminal. The reading should be high. Then place negative lead on No. 3 terminal, reading should be low, etc. If one of these readings is incorrect, the full-wave rectifier can be discarded.

Saturable Reactor

A saturable reactor (fig. 9-42) consists of a coil that is wound around an iron core. It enables a small change in voltage to produce a large change in current. The terminal B is one end of the coil and the other end is L-low, M-medium, or H-high, each corresponding to a different number of turns in the coil which affects the operating characteristics. A saturable reactor can be checked with an ohmmeter for continuity and grounds.

Choke

A choke (fig. 9-43) is used to smooth out a pulsating (rough) d-c. Like the saturable reactor, a choke is a coil of wire wound around an iron core. Its operating characteristics enable it to resist sharp changes in current flow. When placed in a circuit, the choke will smooth out any d-c flow. A choke can be checked with an ohmmeter for continuity and grounds.

CHAPTER 10

OVERHEAD POWER DISTRIBUTION

Power from the generating plant at an advanced base may be carried to the various points of consumption by overhead transmission and distribution lines, by underground cable, or by a combination of both. At most advanced bases, the high voltage developed at the central power station is usually, and preferably, distributed by overhead feeder lines. Such lines are cheaper to build, simpler to inspect, and easier to maintain than underground cables. Obviously, use of underground cables is preferred at airports to prevent hazardous flight conditions.

Voltages developed normally range from 120/208 volts to 7620/13200 volts. The initial generation and distribution system at an advanced base is provided by a 110/220 volt, 3-phase, 4-wire grounded neutral. Replacement may then be provided by a 2400/4160 volt, 3-phase, 4-wire grounded neutral supplied by banks of two or more generators. Finally, as requirements increase, power sources capable of providing the larger voltages are installed.

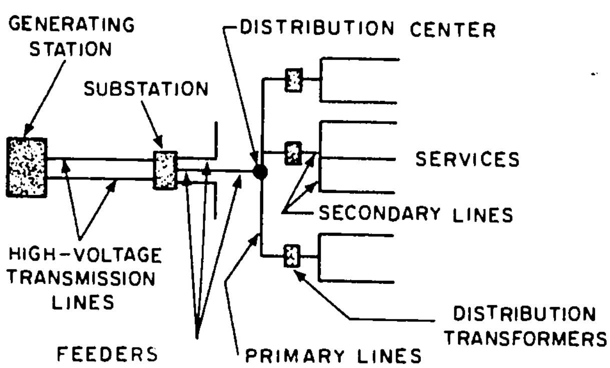


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Figure 10-1.—Transmission and distribution system.

Whether underground or overhead, the distribution system at an advanced base is of the radial type. A representative transmission and distribution system is shown in figure 10-1.

While working on a line crew you will be involved with the various stages of line work. You will begin as a groundman (helper), learning the proper procedures of doing line work, hardware required, special line tools used, and types of transformer hookups. Later on you will work as a lineman, mounting crossarms, stringing wire, and installing protective devices.

Your line crew leader will start off by explaining the project details from a set of blueprints. These details will include the route, class of poles, and type and size of transformers required for the project.

The basic concepts of pole line design are considered in the layout of each powerline job. Factors that are considered in designing the job are: the route, power load requirement, location and size of transformer banks, and class and types of poles suited for the project.

The line work generally accomplished by a battalion can be found in a standard set of drawings, Facilities Planning Guide, P-437, volume I (this replaces the P-140 series, Advance Base Drawings). This publication gives project layouts and lists materials needed to accomplish the project as shown.

This chapter provides information that will be useful to the CE engaged in the installation and maintenance of an overhead power distribution system. Topics covered include pole line components, powerline erection, distribution and current transformers, street lighting fixtures and circuits, and obstruction lighting. A section also is included on troubleshooting, along with a troubleshooter's chart for the series circuit.

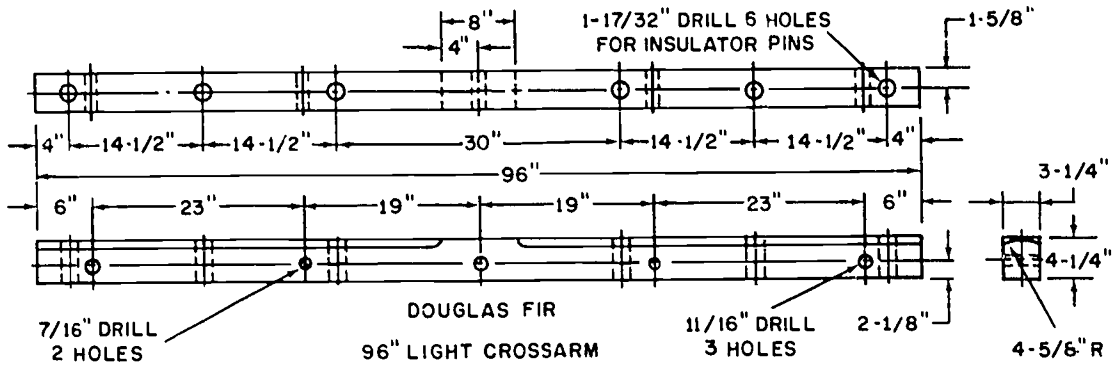

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Figure 10-2.—Crossarms.

POLE LINE COMPONENTS

The basic components in a power distribution system are: poles; crossarms that will go on the poles; insulators and insulator pins; transformers and protective devices. Information on each of these components is given in various sections of this chapter.

POLES

Three types of poles used in distribution systems are: wood, steel and concrete. You will run across all three types but will be working mostly with wooden poles.

Wooden poles are commonly classified as to length, top circumference, and circumference measured 6 feet from the butt end. The length varies in 5-foot steps and the circumference at the top varies in 2-inch steps. The circumference, measured 6 feet from the butt end, determines to which class (numbered from 1 to 10) a pole of a given length and top circumference belongs. The classification from 1 to 10 determines the strength to resist loads applied 2 feet from the top.

CROSSARMS

Crossarms are the crosspieces on a pole which support the insulators and conductors of a line. There are four widely used standard sizes of wooden crossarms; namely, 3 1/4" by 4 1/2", 3 1/2" by 4 1/2", 3 3/4" by 4 3/4", and 4" by 5". The first two of these sizes are standard for distribution work, and the latter two sizes are for transmission work. Crossarm length depends on the number of pins and the separation between pins. Standard crossarms include two-, four-, six- and eight- pin sizes with standard pin spacing of 30 inches between pole pins and 14 1/2 inches between outside pins as shown in figure 10-2.

INSULATOR PINS

Insulator pins are used to mount the insulator on the crossarm. They may be either wood or steel (see fig. 10-3). For wood pins, well-seasoned locust in standard sizes for the arms and insulators is used. For galvanized steel pins, use the minimum lengths recommended by the insulator manufacturer. They are available in two sizes; long shank for use on wood arms and short shank for use on steel arms.

Standard-pin thread sizes are 1 inch and 1 3/8 inches. With insulators having porcelain threaded pinholes, use pins having lead thread. Use solid steel threads on pins only for insulators with metal thread pinholes.

INSULATORS

Insulators for overhead lines are classified into three classes: (1) pin, (2) suspension, and (3) [illegible] type. The porcelain pin [illegible] in figure 10-4 are the most

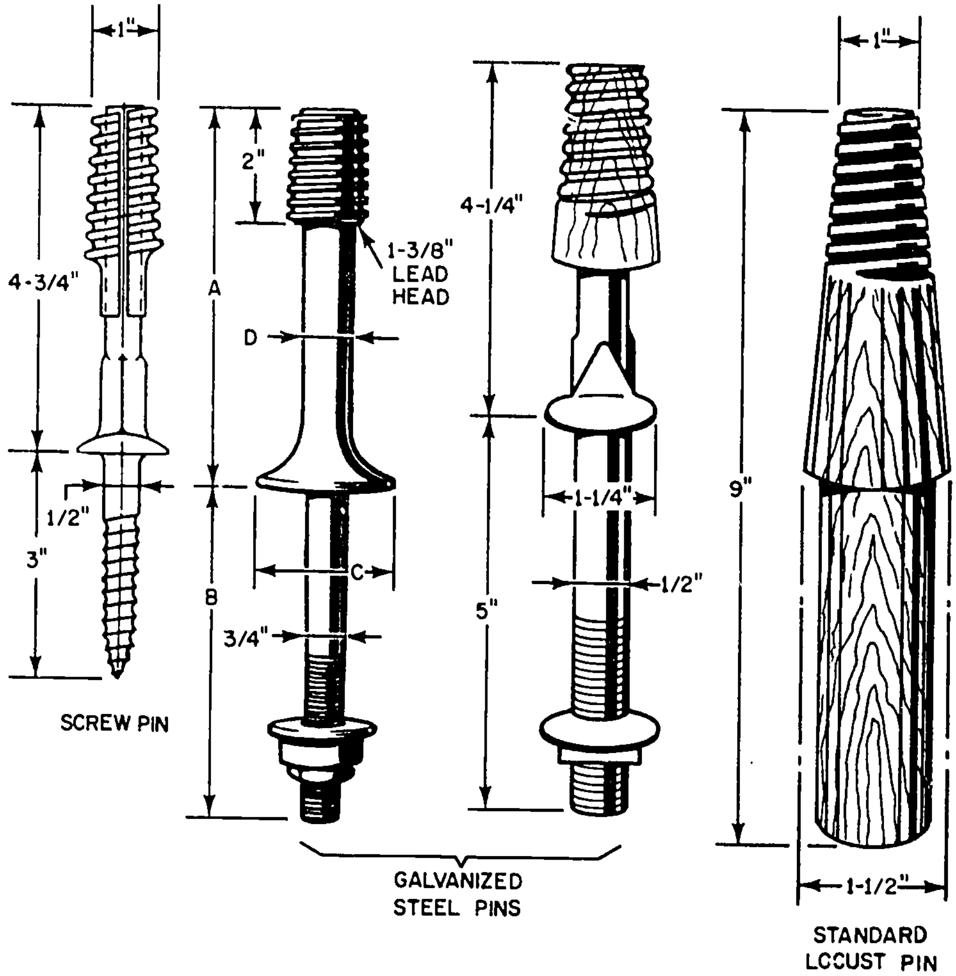

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Figure 10-3.—Insulator pins.

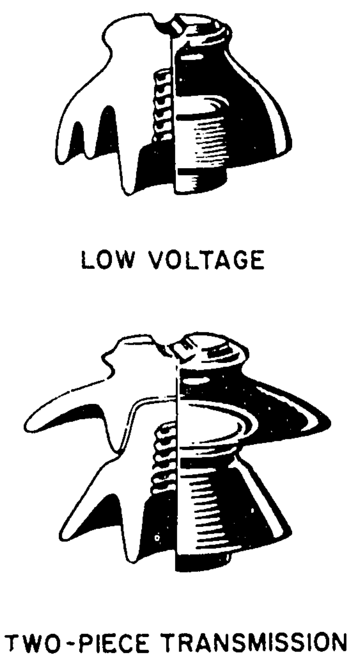
commonly used. The one-piece type is used for low voltage. The two-piece type (and larger size types) is used on high voltage lines. One-piece insulators are used for voltages below 23,000 volts; two-piece insulators for 23,000 to 44,000 volts; three-piece insulators for 44,000 to 66,000 volts; and four-piece insulators for 66,000 to 88,000 volts. The layers on these insulators are called petticoats or skirts. They help to spill rain and provide a long, dry arc-over path.

Suspension insulators (see fig. 10-5) were developed when voltages were increased above 44,000 volts. They are a big advantage since pin insulators become quite heavy at these high voltages and make it difficult to obtain sufficient mechanical strength in the pin to support the insulator.

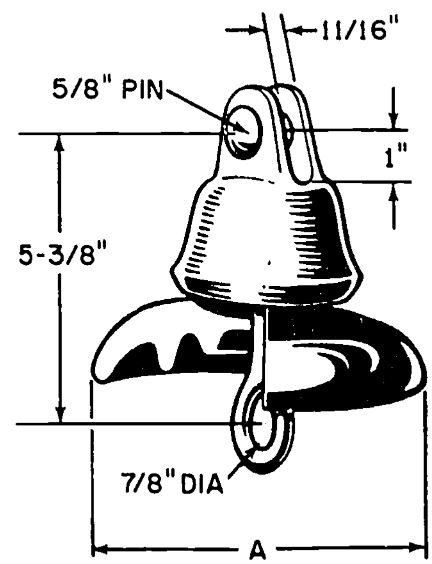
Strain (or clevis) type insulators are used on primary systems at corners, angles, dead ends, suspended buses, and wherever pins do not provide adequate support. They are built the same as suspension type insulators but are stronger mechanically.

HARDWARE

Hardware consists of a variety of bolts, nuts, screws, braces and clamps, which enable



73.353
Figure 10-4.— Pin type insulators.



73.354
Figure 10-5.— Suspension type insulator.

you to mount crossarms, string guy wires, and hang transformer banks. Figure 10-6 is an example of some of the common types of hardware with which you will be working.

PROTECTIVE DEVICES

Circuit protective devices are divided into two main categories: primary devices and secondary devices. The primary devices protect the high-voltage transmission lines, the transformer installations, and the substations. The secondary devices protect the electrical equipment on the secondary side of the transformers—that is, the lighting circuits, motors, and other appliances which are the final consumers of power. In this chapter we are mainly concerned with primary devices. Information on secondary devices is presented in the chapter on interior wiring (chapter 8).

The primary protective devices consist of fused disconnect switches, circuit breakers, lightning arresters, and grounds.

Disconnect switches used in transmission lines are not, strictly speaking, true protective devices, because they are used for isolating only certain parts of the line. By opening a disconnect switch, linemen can cut a line off from the main line or circuit, for repair work, without deenergizing the complete circuit. This type of switch is made for single-pole or gang operation. Although it may be motor-operated, it is more commonly operated by hand on the ground, by throwing a switch handle. Both handle and rod must be grounded. A handle-to-the-ground operated gang disconnect switch must also have some means of locking the switch in ON or OFF position, to prevent operation by an unauthorized person. Figure 10-7 shows gang-operated disconnect switches.

Primary cutouts or fused disconnect switches are placed ahead of tranformers, in the primary feeder, to open the circuit should the transformer become overloaded to a dangerous point. They are also used to isolate the transformer in order to make repairs or changes on the secondary line. Figure 10-8 shows a 100-ampere 7500-volt fuse disconnect equipped with a standard fuse holder and fuse link. By substituting the switch blade (shown at left of cutout) for the fuse holder, the cutout can be used as a straight disconnect switch. The switch blade has a 200-ampere carrying capacity. Figure 10-9 shows open-type fused disconnect switches. Disconnect

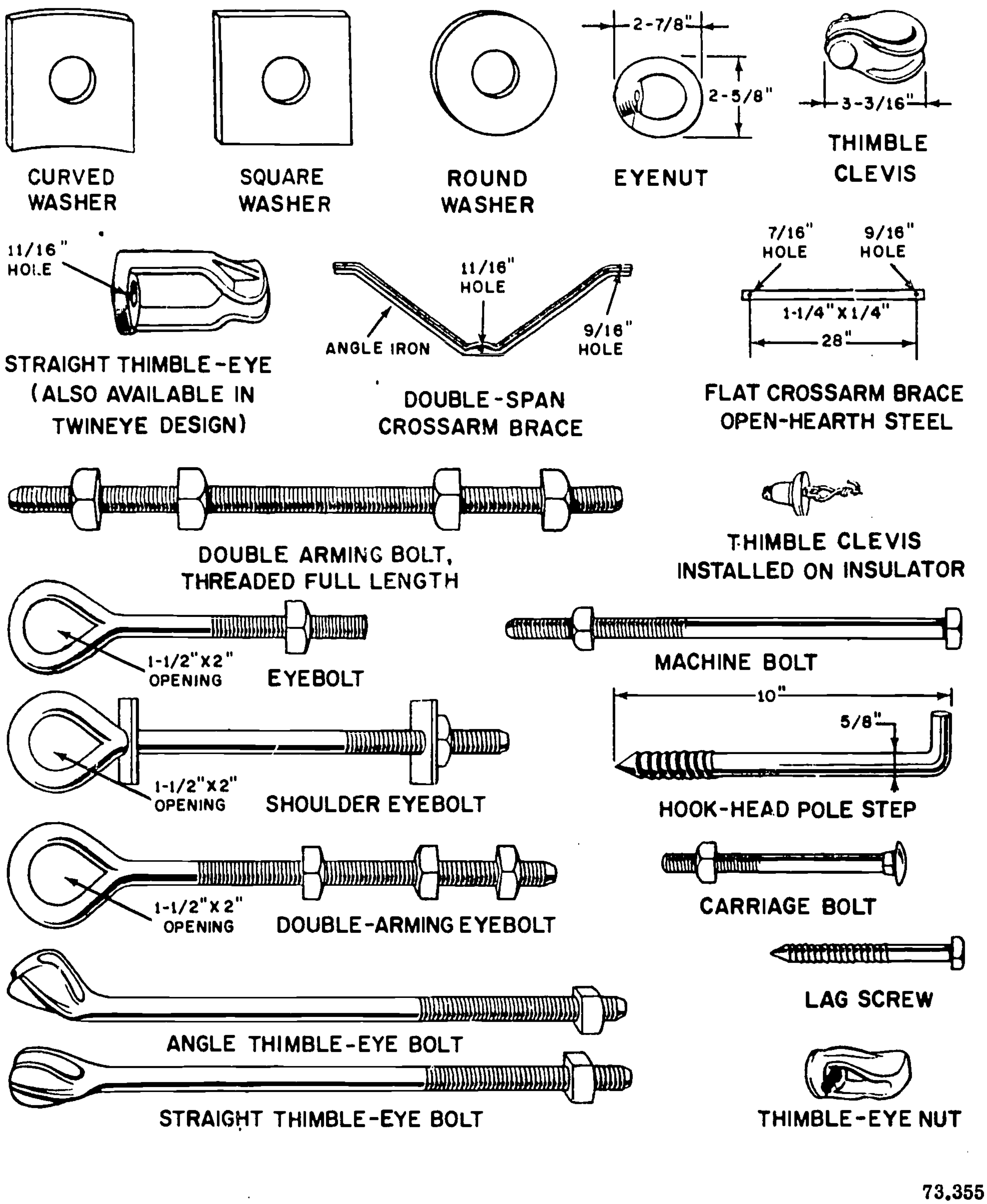
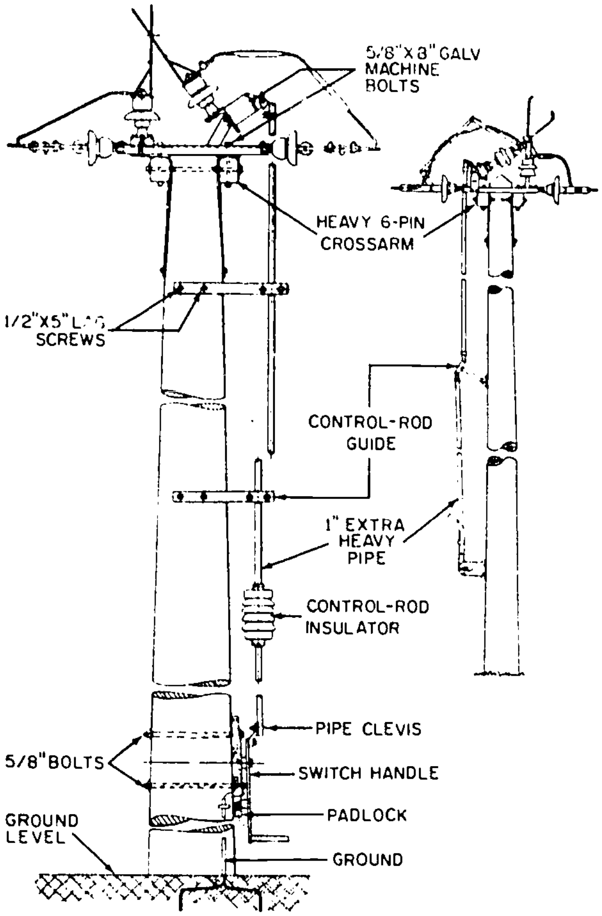
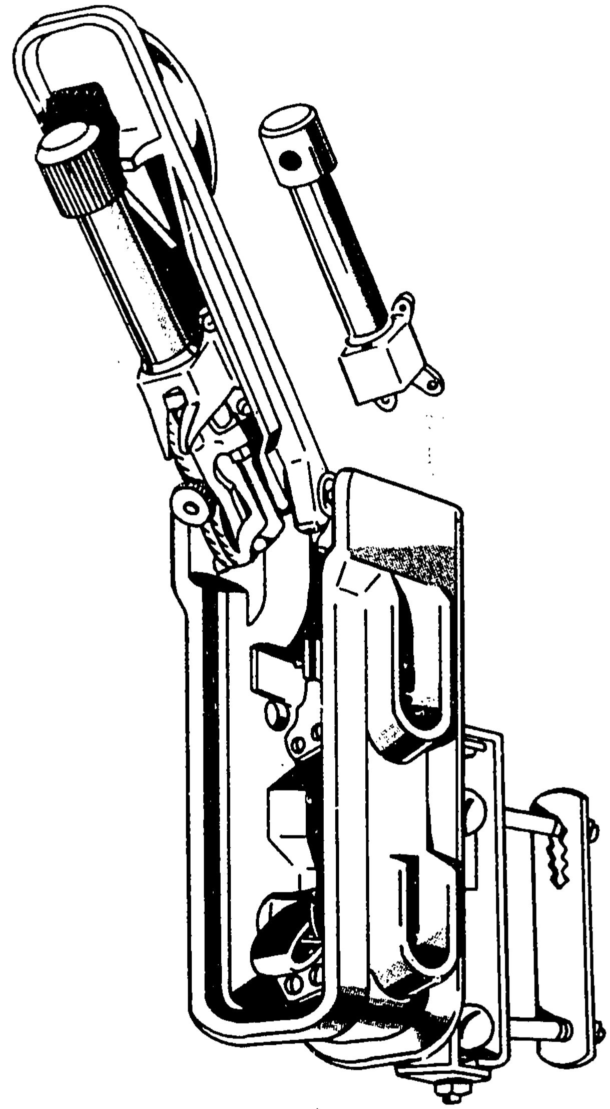


Figure 10-6.—Pole line hardware.



73.356
Figure 10-7.—Gang-operated disconnect switches.

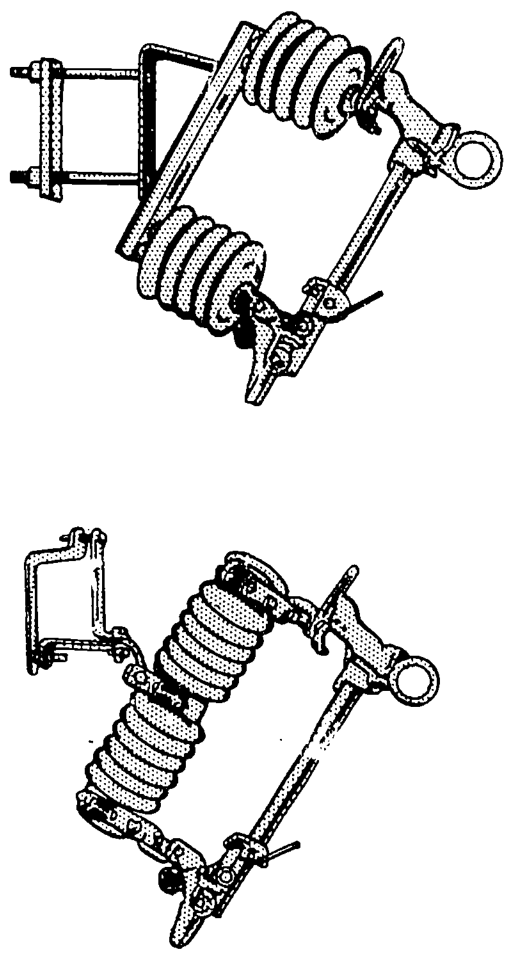


73.101
Figure 10-8.—Fused cutout and disconnect blade.

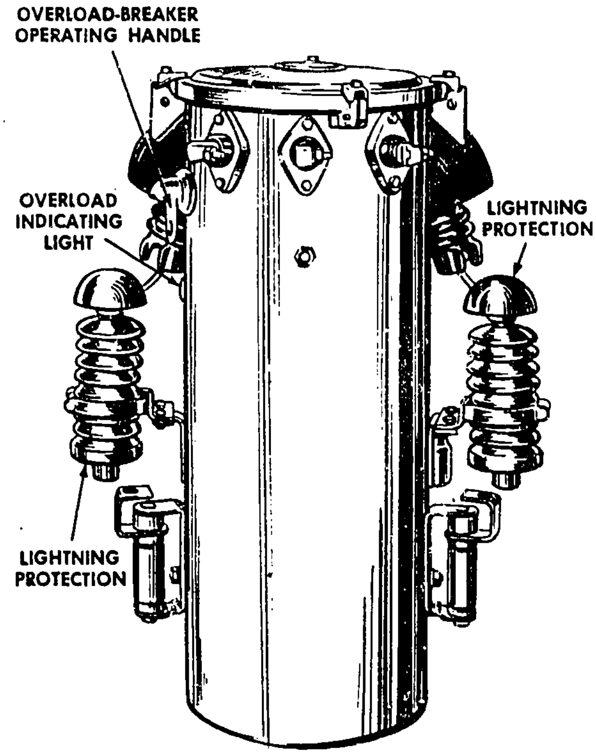
switches are generally used in the primary circuit when opening the circuit is necessary under voltage but with little or no load current.

Oil circuit breakers are used in circuits carrying more than 600 volts. One of these can be used to open a circuit automatically upon overload. They are generally designed and connected for one or more automatic reclosings, thus restoring service rapidly when a fault has cleared itself. Oil switches are, therefore, used where control of a high-current circuit as well as protection from overload and short circuit are desired.

Some transformers are protected against excessive voltages and overload by lightning arresters and circuit breakers which are integral parts of the transformer (fig. 10-10). A heavy overload on the secondary circuit opens a breaker inside the tank, disconnecting the transformer from the load. Overloads not large enough to damage the transformer cause an indicating light on the outside of the tank to turn on. The glowing light indicates that the load is too large. Unless the overload is only temporary, the transformer must be replaced by one of larger capacity,



73.102
Figure 10-9.—Open-type fused disconnect switches.



73.103
Figure 10-10.—Self-protected transformer.

or some of the load must be transferred to a different transformer.

LIGHTNING ARRESTERS

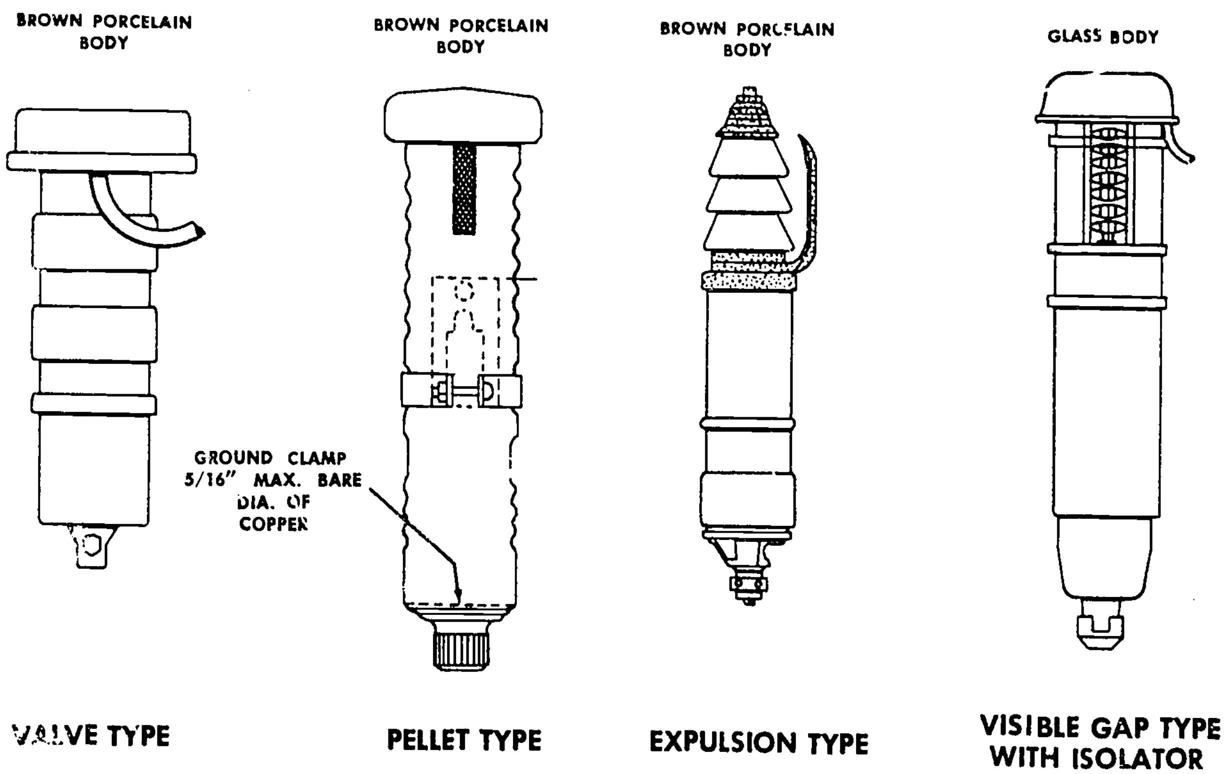
Various types of lightning arresters are used in transmission work. A few examples of lightning arresters which you may encounter in your work are shown in figure 10-11. A lightning arrester protects a line against the very high voltage which occurs when lightning strikes. When a voltage rise above normal occurs, an arch forms across a horn-gap in the arrester and the overload passes from the horn-gap to ground through the ground wire or other grounding device. This is the same action as a safety valve on a steam boiler. When an excess of pressure builds up in the boiler, the valve relieves the excess by opening up. It then closes automatically as the pressure returns to normal.

POWERLINE ERECTION

The erection of powerlines is a responsibility of the CE 3 and 2. This phase of our discussion will acquaint you with various duties involved in the erection of powerlines; for instance, preparing poles, erecting the poles, stringing and tying conductors, and so on. We will also cover safety apparel and equipment, care of pole-climbing equipment, and safety precautions to be observed in the erection of powerlines.

PREPARING POLES

At an advanced base you may have to use standing trees as poles. If this is so, select the straightest trees you can find and trim them.



73.104

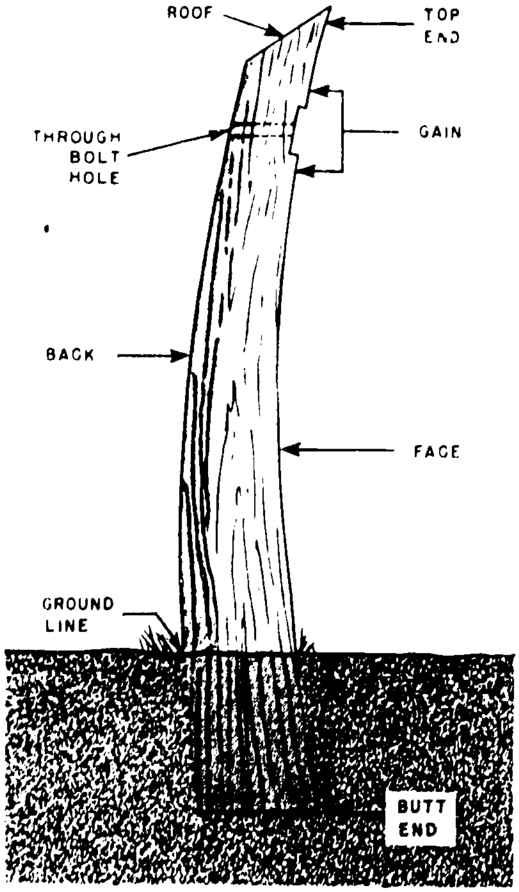
Figure 10-11.—Types of lightning arresters.

Trimming consists of cutting branches off flush with the trunk. This procedure is necessary to make the pole safe for a lineman to climb using tree gaffs.

Most of the poles you will use will be already trimmed and treated with creosote (to prevent rotting) before they arrive at the site. Creosote is a toxic compound that will blister the skin. Therefore, use gloves when handling or climbing creosote-treated poles and AVOID touching your eyes with the gloves. Be sure to have your sleeves rolled down.

The next step is to cut the "roof" (a roof-like cut at the upper end, made by sawing a single slant cut that drains toward the back of the pole) and the "gains" (a gain is a notch in which a crossarm is set). This cutting should be done with the pole in a rack of some kind which will hold one end of the pole above the ground. If the pole is curved, it should be set in the rack so that the curve or sag is toward the ground. Then cut the roof diagonally and the gain or gains on the upper surface, so that the relation of roof to gains is as shown in figure 10-12. Remember that the gain is always cut on the face of the pole, and the face is the inside of any curve the pole may have. Following this rule ensures that the pull of wires on the crossarm will be against the curve of the pole. Remember, too, that the slope of the roof should be parallel to the wire lines, not across them. The reason for this is to ensure that water draining off the roof will run down the back of the pole, and not into the crossarm gains.

The center of the first or top gain should be located 12 in. from the top of the pole. Since the width of the gain is the height of the crossarm, measuring half the height of the crossarm above and below the center of the gain will give you the top and bottom of the gain. The gain should be cut about 1/2 in. deep. It is good practice to make the gain slightly concave, so the crossarm will bear solidly against the outer ends.



29.233
Figure 10-12.—The parts of the pole.

The spacing between succeeding gains depends on the voltage in the lines. For voltages up to 8700 volts the minimum spacing is 24 in. For voltages from 8700 volts to 50,000 volts the minimum spacing is 48 in.

The next step is to bore the hole for the crossarm through-bolt in the center of the gain (see fig. 10-12). The standard through-bolt has a diameter of 5/8 in. The diameter of the bolt hole should be 11/16 in. To center the hole, draw intersecting diagonal lines across the gain.

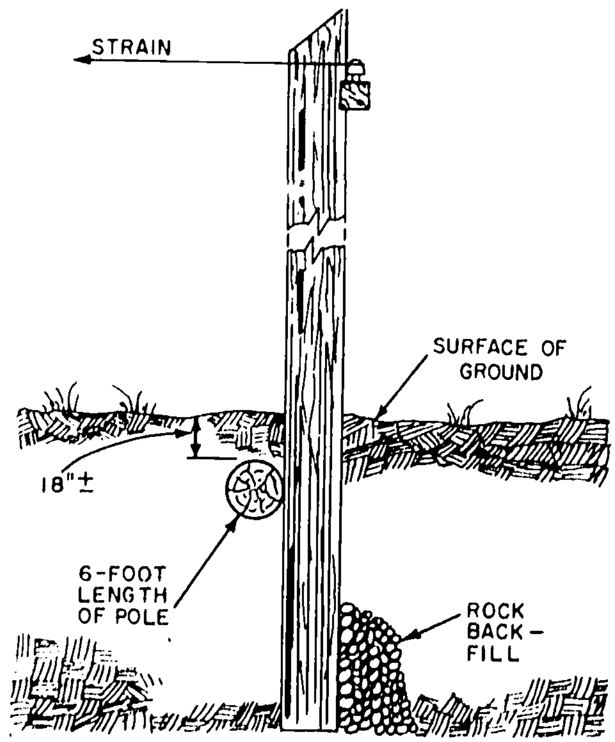
DIGGING POST HOLES

The depth for a pole hole depends on the length of the pole and the composition of the soil. A hole in firm, rocky terrain does not need to be as deep as a hole in soft soil. Table 10-1

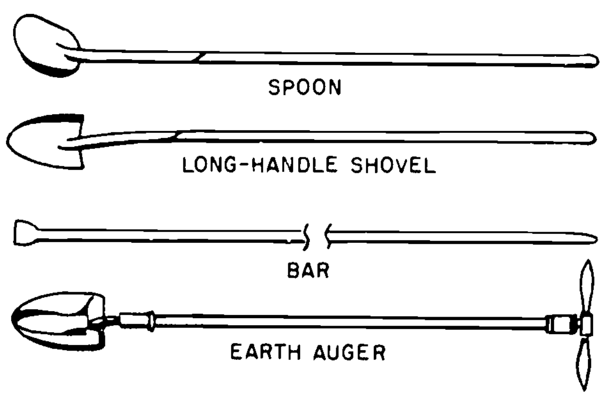
Table 10-1.—Depth for setting pole in soil or rock

Length of pole (ft)	Setting depth (ft)	
	In soil	In rock
20	5.0	3.0
25	5.5	3.5
30	5.5	4.0
35	6.0	4.0
40	6.0	4.0
45	6.5	4.5
50	7.0	4.5
55	7.5	5.0
60	8.0	5.0

73.310



73.69
Figure 10-13.—Cribbing a pole with stone and log.

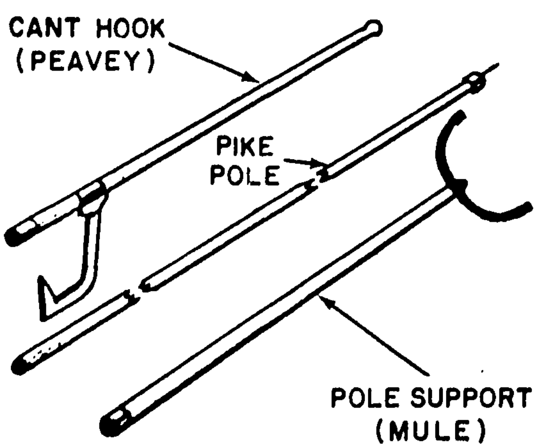


29.234

Figure 10-14.—Digging tools.

gives recommended post-hole depths for poles from 20 to 60 ft long in firm soil and in rock.

A pole set in sandy or swampy soil must be supported by guys or braces, or by "cribbing." Cribbing means the placement of some firm material around the part of the pole that is below ground. One method of cribbing is to sink an open-bottom barrel in the hole, set up the pole in the barrel, and then fill the space around the base of the pole with concrete or small stones after the pole has been plumbed (brought to the vertical). Another method of cribbing is shown in figure 10-13.



29.235

Figure 10-15.—Pole tools.

There may be a power-driven hole-digger available, but in the absence of one of these the holes must be dug by handtools (fig. 10-14). You use a "digging bar" to loosen the soil. About the first 2 ft of depth can be removed with a short-handle shovel. Below that you loosen the earth with an earth auger or long-handle shovel, and haul it up with a long-handle device called a spoon.

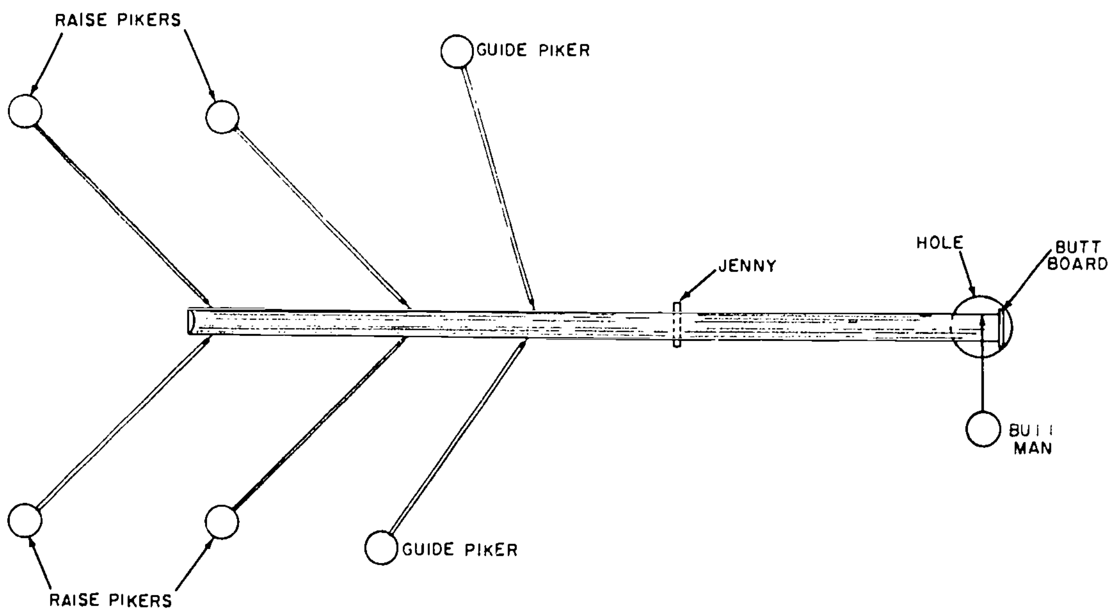
A hole should have a diameter about 6 in. larger than that of the base of the pole, to allow room for tamping backfill. It should be a little larger at the bottom, to allow for plumbing the pole.

ERECTING POLES

If a line truck with winch and A-frame is available, the job of erecting poles is simple. A sling is placed around the approximate midpoint of the pole and the winch heaves it up. The truck then proceeds to the hole, and the base of the pole is guided in as the winch lowers away. Since the butt or base is heavier than the top end, the pole will be raised to an almost vertical position.

In the absence of this equipment, the pole must be "piked up"—meaning that the pole is placed with base adjacent to the hole and the upper end supported on either a "mule" or a "jenny." A jenny is a wooden support made in the form of an X, while a mule is a wooden support made in the form of a Y. The upper end is then "piked" into the air by men using pike poles. A pike pole and mule are illustrated in figure 10-15.

This procedure is illustrated in figure 10-16. The "butt man" holds and guides the butt of the pole with a cant hook or "peavey" (see fig. 10-15). This is a handle, the hook being designed to grasp the pole when pressure is applied to the handle. As the upper end of the pole is raised, a man keeps the jenny or mule in approximate contact by moving it toward the butt. The "butt board" is a length of plank, set in the hole and long enough to protrude above the surface. It prevents the butt of the pole from sliding past the hole, and also prevents the butt from caving in the side of the hole. After the pole



73.70

Figure 10-16. — Piking up a pole.

has reached upright position, it is "faced" — meaning that it is rotated with the cant hook to bring the crossarm gain to proper position. On a straight line it is the custom to set adjacent poles with crossarms facing in opposite directions, as shown in figure 10-17. This procedure, called facing "gain to gain" or "back to back," provides for maximum strength in the line.

On a curve the gains must be set so that the crossarm is on the side of the pole nearest the center of the curve, as shown in figure 10-18.

After the pole has been faced, it must be plumbed vertical. This is done by four pikers on four sides of the pole, acting on signals given by one man who sights along the line and another who sights from one side. In some cases a small amount of rake or lean (approximately 12 inches) is left to allow for a wire strain or the normal give of a guy.

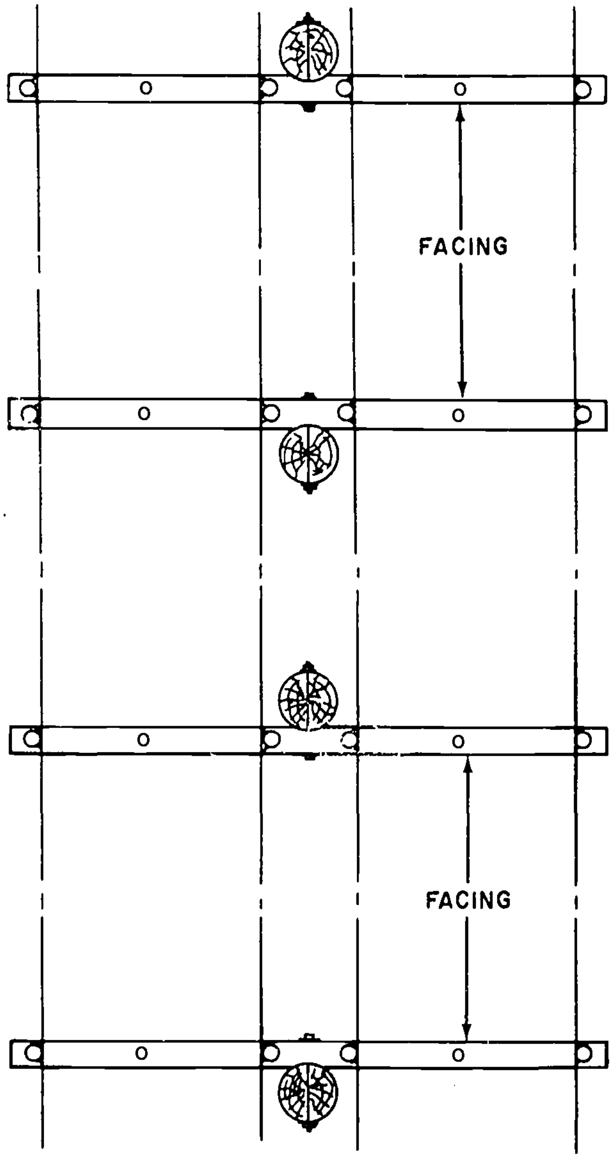
After the pole has been plumbed, the hole is backfilled and the backfill tamped down hard. Backfilling should be done gradually, in shallow layers, with each layer thoroughly tamped down. Usually two or three men tamp while a single man shovels. When the hole has been filled to the ground line with tamped backfill, the remaining excavated soil is banked in a mound around the base of the pole, to allow for subsequent settling.

SAFETY IN POLE RAISING

As a pole is being raised, it is safest to assume that at any moment something may slip or break. Stand as far away from the pole as possible if you are not in the raising crew.

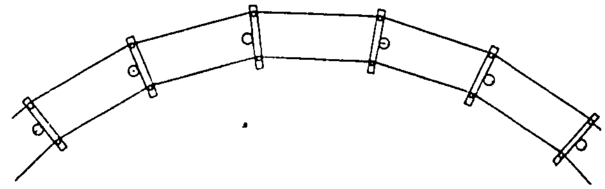
The pike-pole method of setting poles should not be used unless there are enough men to do the work safely. In using pikes, the men must stand far enough apart so that they will not interfere with each other. Never brace a pike pole on your stomach. If the pole shifted your way, you would not be able to get clear. Unmanned pikes alone should not be relied upon to support a pole while a man is on it. All pike pole tops should be kept covered at all times except when actually in use.

Workmen should not be on poles while they are being plumbed, canted or tamped.



73.71
Figure 10-17.—Facing crossarms on a straight line.

A "guy" is a brace or cable which is "anchored" in some fashion at the lower end, and secured to a point on the pole at the other, and serves to brace the pole in position. Normally, cable or wire guy is made of 7-strand galvanized steel. There are various types of guys used, some of which are as follows:



73.72
Figure 10-18.—Facing crossarms on a curve.

A "line" guy is one installed in a straight pole line and parallel to the line, to reinforce the line against stress caused by broken conductors.

A "head" guy is one which runs from the top of one pole to a point below the top on another pole.

An 'arm" guy is one which runs from the end of a crossarm to the next adjacent pole. It is used when a line dead ends at the end of a crossarm.

A "storm" guy (fig. 10-19) is one installed in a line to prevent the entire line from being pulled down in the event that line conductors should break at some point in the line. A storm guy consists of two line guys (that is, guys running parallel to the line) and two side guys (guys running crosswise to the line). Storm guys are usually installed at intervals of 1/2 mi. to 1 mi.

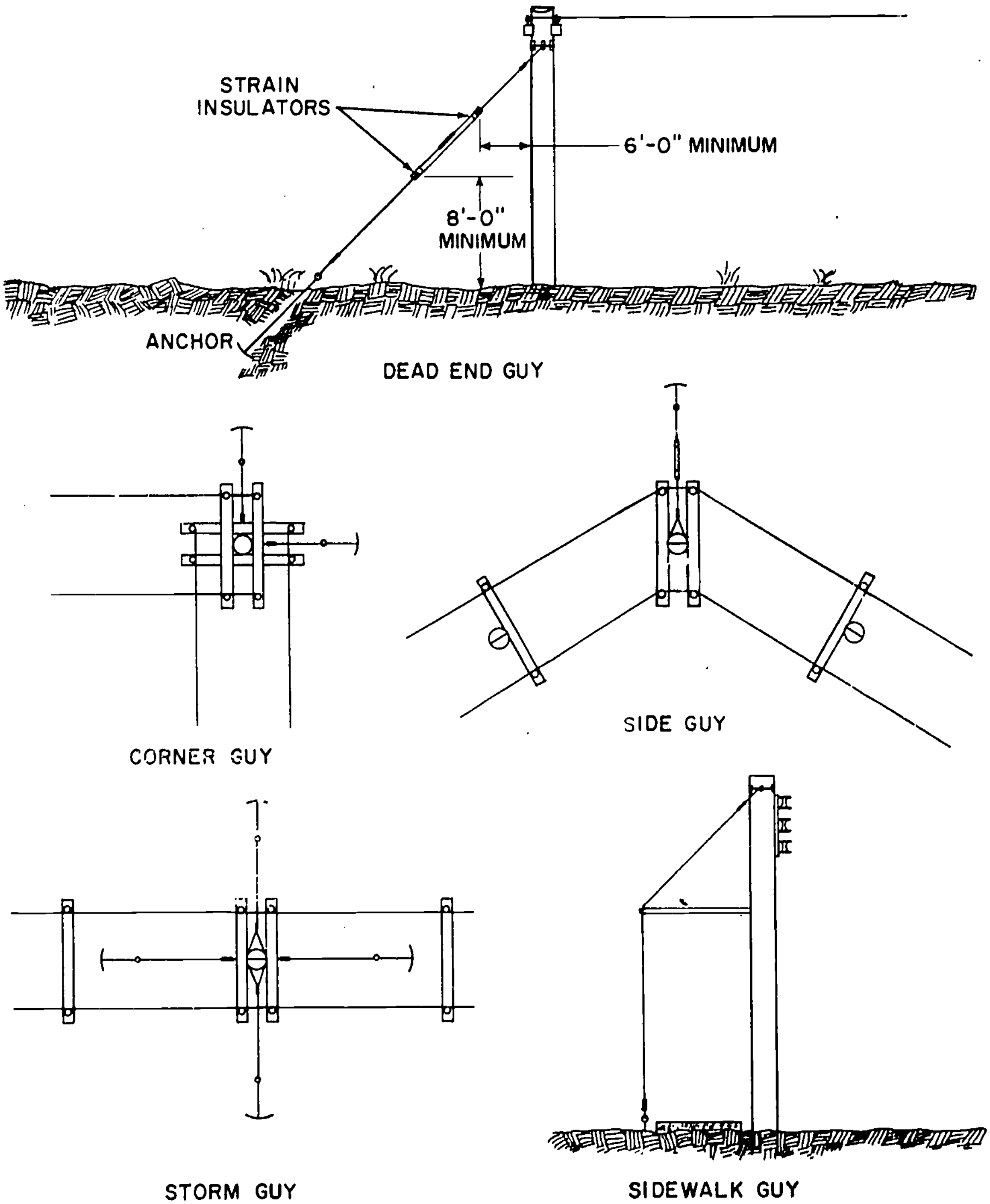
A "sidewalk" guy is outrigged (as shown in fig. 10-19), so the guy will not obstruct pedestrain traffic on the sidewalk.

A guy which runs from the top of a pole to a ground anchor is called a "down" guy.

A "stub" guy runs from the top of a pole to the top of a shorter pole called a stub. The stub is itself braced by a down guy.

Locating Guys

Guys are installed at any place in the line where the stress of the conductors could pull the crossarms or the pole out of proper position. It is not possible to mention all the situations which call for guying, but some important guy locations are as follows:



73.73

Figure 10-19.—Types of guys.

333

DEAD ENDS.—Dead ends or terminals must be guyed as shown in figure 10-19.

CORNERS.—Corners (that is, poles where the line changes direction radically) must be guyed as shown in figure 10-19.

BRANCHES.—Where a branch line takes off from a main line, a side guy (fig. 10-19) should be installed to support the stress of the branch line.

ANGLES.—A corner is, of course, an angle, but it is an angle which comes close to 90°. When a line makes ANY angle, however slight, a side guy should be installed. For a large angle, two or more guys should be installed.

CROSSINGS.— Electric lines crossing railway tracks must be equipped with head guys installed on poles on both sides of the crossing. These guys run from the top of the pole adjacent to the tracks to about midway of the next pole.

Strain Insulators

All guys on powerlines should have one, preferably two, strain insulators installed in the guy to break contact between the upper part of the guy and the part low enough to be contacted by persons on the ground. The lower insulator should be at least 8 ft above the ground and the upper one should be placed at least 6 ft from the pole to prevent electrical contact (fig. 10-19).

GUY ANCHORS

For securing the lower or ground ends of guys there are various types of "anchors" used, some of which are illustrated in figure 10-20. The "Never Creep" anchor (this is a trade name) is installed by digging a hole about 8 in. in diameter, at about a 45° angle and sloping down toward the pole. After the hole is dug, a rod is driven in the ground in line with the guy wire from the top of the pole. This rod intersects the hole at a right angle about 6 ft from the surface. The plate part of the anchor is then placed over the rod and locked on by the slot plate. A Never Creep anchor is shown in view A of figure 10-20.

The "expanding anchor" (view B of fig. 10-20) is installed by digging an 8-in. hole in line with the guy wire from the pole or at about a 45° angle. The anchor is put in the hole, and a heavy tamper is slipped over the rod. The anchor is rammed with the tamper until it expands to its full width. This usually takes about five or six blows with the tamper.

The "log" anchor (view C of fig. 10-20) is a simple do-it-yourself type which is very effective in soft or sandy soil. The log usually consists of a 6-ft long section of a pole. The trench is dug at right angles to the line of the guy, to a depth of at least 6 ft, and long enough to receive the log. A narrow trench, to accommodate the guy, is dug as shown. A threaded rod is run through a hole in the log and secured with nut and washer. The rod is long enough to permit the eye in the upper end to reach a point 6 in. above the ground line.

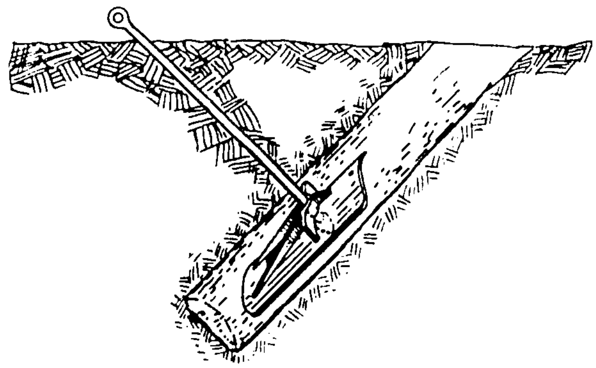
A "screw" type anchor is one which can be "screwed" into the ground as shown in view D of figure 10-20. A shallow hole is dug to start the screw blade, and the rod is then rotated by two men using a bar-toggle run through the eye.

CLIMBING POLES

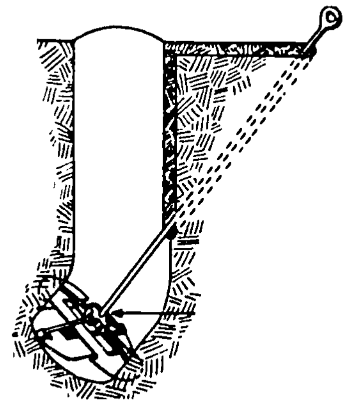
To climb a wooden pole or tree you will use the equipment shown in the lower part of figure 10-21. The "stirrup" fits under the arch of your foot, and the leg iron runs up the inner side of the calf of your leg. This puts the "gaff" in a position on the inner side of your foot where you can drive it into the pole or tree as you climb. Two leather straps run through the loop straps and hold the climber tightly against your calf and ankle. The "leather" pad keeps the upper end of the climber from digging into your leg.

The term "leather" refers not only to treated animal hides but also to neoprene impregnated nylon products such as body belts, safety straps, and leg straps. These non-leather items are cleaned with soap and water and are available to the battalions.

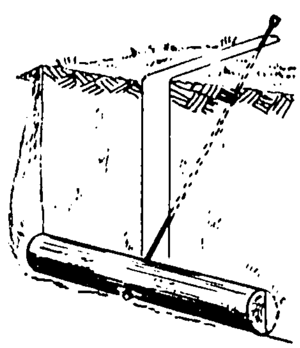
The "safety strap" and "body belt" shown in the upper part of figure 10-21 are what might be called your extra pair of hands when you work aloft. The body belt, strapped around your waist, contains various pockets for small tools. The



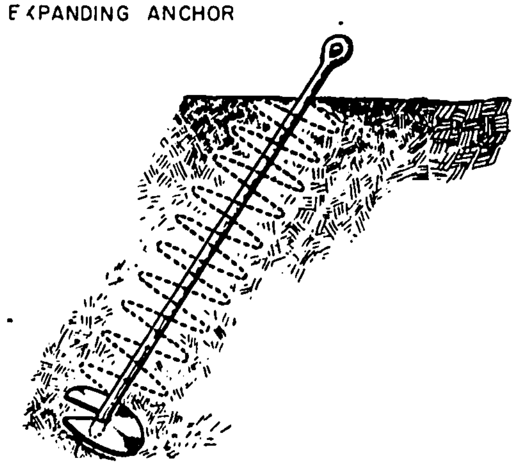
A NEVER CREEP ANCHOR



B EXPANDING ANCHOR



C LOG ANCHOR



D SCREW TYPE ANCHOR

73.74

Figure 10-20.—Types of guy anchors in general use.

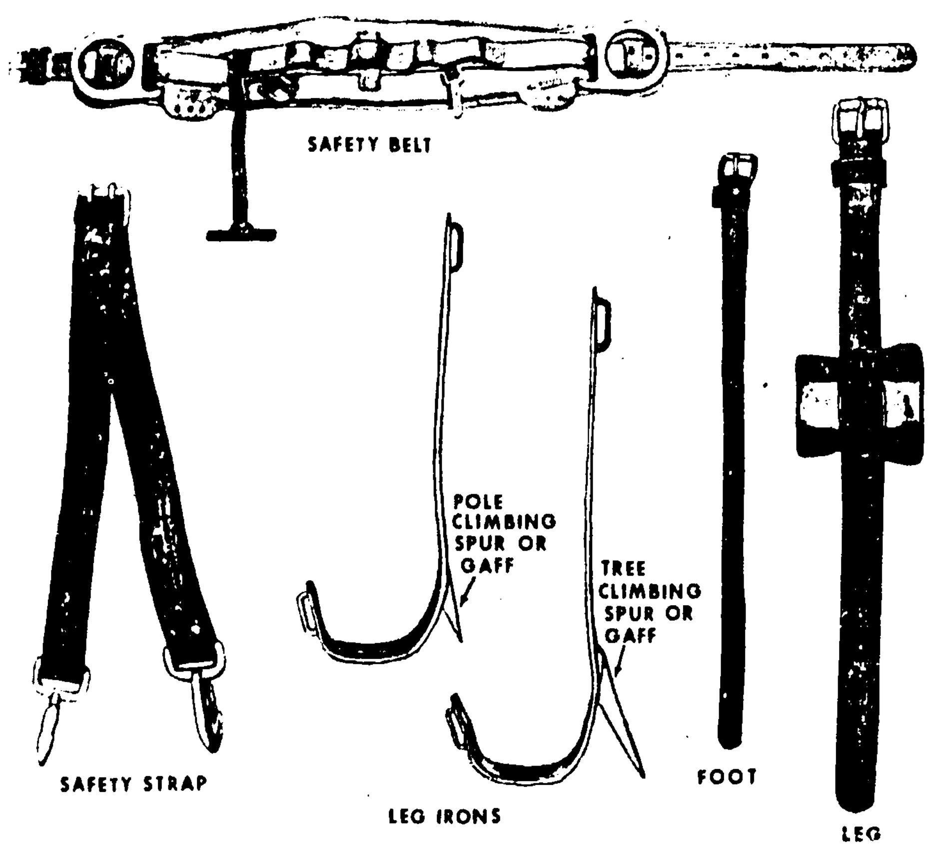
safety strap is a "leather" belt with a tongue-type buckle (keeper snap) at each end. While you are climbing you will have the safety strap hanging by both ends from the left ring (called a D-ring because of its shape) on the body belt. When you are at working position, you will unsnap one end of the safety strap, pass it around the pole, and hook it to the right "D" ring on the body belt. One adjustable buckle permits variation to suit the lineman and the circumference of the pole. You can now lean back against the safety strap and maintain a steady, comfortable, and SAFE position.

Care of Climbing Equipment

To a lineman the term "burning" a pole means the highly unpleasant experience of sliding all the way, or a good part of the way, down a pole as a result of defective equipment or some error in climbing technique made on the way up. The burning you get doesn't need to be explained in detail, and besides burning you may get a good many splinters. However, climbers, body belt, and safety strap should keep you up where you belong—if you use them properly and take proper care of them.

The body belt and safety strap require continuous inspection. Look for:

1. Loose or broken rivets.
2. Cracks, cuts, nicks, or tears in leather.
3. Broken or otherwise defective buckles.
4. Deffects in safety-belt snap hooks and body-belt D-rings.



73.357

Figure 10-21.—Pole-climbing equipment.

5. Worn leather.
6. Enlarged tongue holes for belt buckles.

If you discover any of these defects, turn in the equipment and replace it.

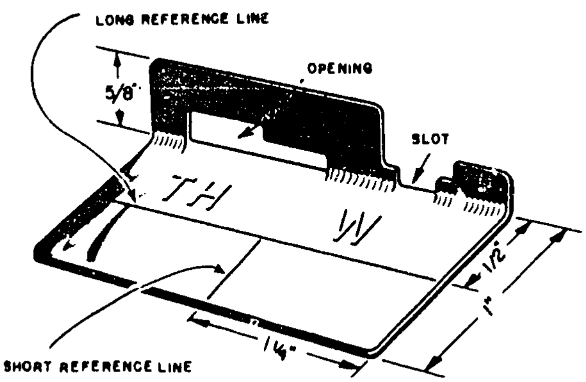
You must periodically perform maintenance work on the leather parts of your climbing equipment. Cleaning comes first. Use a damp sponge and a mild soap. Work up a thick, creamy lather. Then wash the soap off and wipe the belt with a dry cloth.

Next, to make the genuine leather belt soft and pliable, lather well with saddle soap. Work the lather into all parts; then place the belt in the shade to dry. After the lather has nearly dried, rub down the leather with a soft cloth.

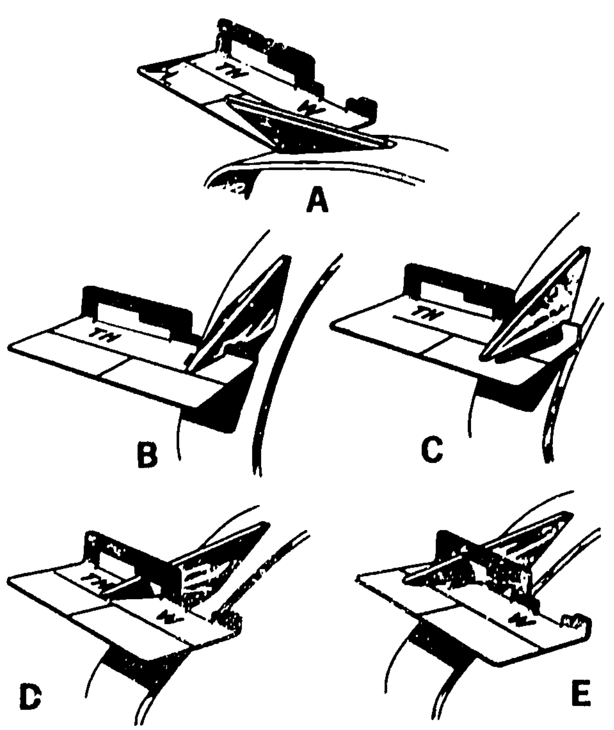
Body belts and safety straps made of genuine leather require oiling about every 6 months. Be sure the leather is clean before applying oil. Use about 2 teaspoonfuls of neat's-foot oil, working the oil in gradually. Place the belt in a shady place and allow to dry for 24 hours. Then rub down with a soft cloth.

Always, before you climb a pole or tree, inspect the climbers for the following defects:

1. Broken or loose straps.
2. Stirrup worn to a thickness of 1/8 in. or less.
3. Length of pole gaff or less than 1 1/4 in. as measured along the inner surface.
4. Length of tree gaff not less than 5 1/2 in. as measured along the outer surface and not less than 3 1/2 in. along the inner surface.
5. Difference in gaff lengths of more than 1/8 in.



26.259
Figure 10-22.—Climber's gage.



26.260
Figure 10-23.—Use of climber's gage.

If you find any of these defects, turn in your climbers for a new pair.

Climber's Gage

To minimize certain dangers which can occur from neglect of the climbers, make sure you check your gaffs frequently using a climber's gage (fig. 10-22). This gage is used to check the dimensions of gaffs. These must be within certain tolerances or the climber will "cut out" or lose contact with a pole or tree.

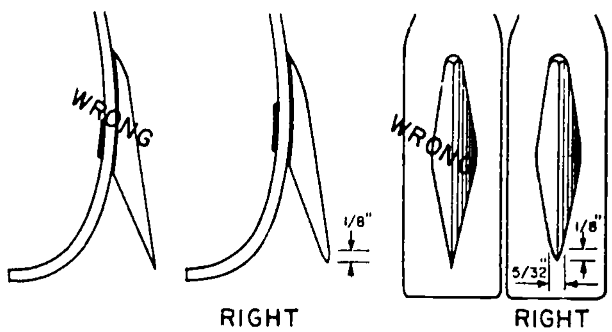
Measurements of the length, width, and thickness of the gaffs are made as follows.

LENGTH. Place the lined face of the gage against the inner surface of the gaff with the short edge of the gage held tightly against the crotch (fig. 10-23A). The crotch is the point where the gaff joins the leg iron. If the point of the gaff extends to or beyond the short reference line, the length of the gaff is satisfactory.

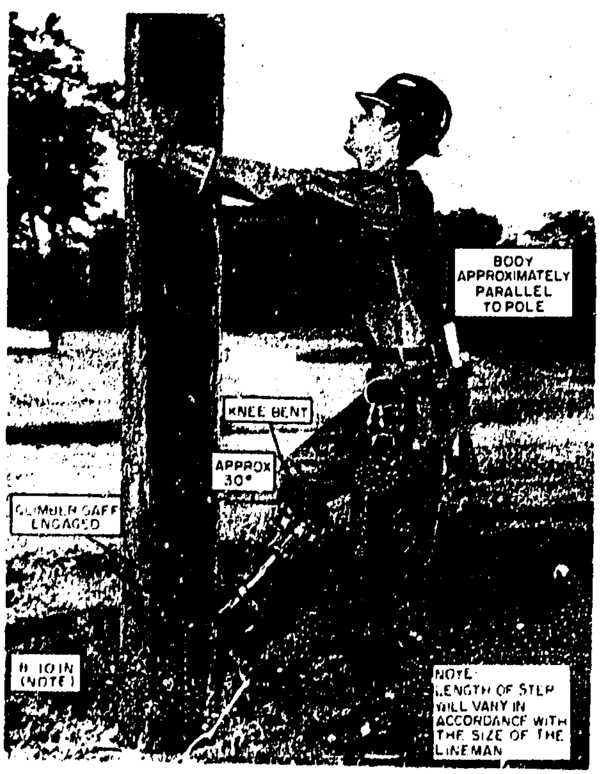
WIDTH. Insert the gaff as far as possible through the small slot marked W, with the inner surface of the gaff resting against the lined face of the gage (fig. 10-23B). If the point of the gaff does not extend beyond the long reference line, the width of this section of the gaff is satisfactory. Insert the gaff as far as possible through the large slot marked W, with the inner surface of the gaff toward the lined face of the gage (fig. 10-23C). If the point of the gaff does not extend beyond the far edge of the gage, the width of this section of the gaff is satisfactory.

THICKNESS. Insert the gaff as far as possible through the small opening marked TH, with the inner surface of the gaff resting against the lined face of the gage (fig. 10-23D). If the point of the gaff does not extend beyond the reference line, the thickness of this section of the gaff is satisfactory. Insert the gaff as far as possible through the large opening marked TH, with the inner surface of the gaff resting against the lined face of the gage (fig. 10-23E). If the point of the gaff does not extend beyond the far edge of the gage, the thickness of this section of the gaff is satisfactory.

Sharpen any dull gaffs by taking long strokes with a file from the heel to the point of the gaff, removing only enough material to make a good point. NEVER USE A GRINDSTONE OR EMERY WHEEL TO SHARPEN GAFFS, since the metal may become overheated and lose its strength



26.261
Figure 10-24.—Sharpening the gaffs.



73.311
Figure 10-25.—Starting to climb a pole.

(temper). Never sharpen the gaff to a needle-point (fig. 10-24) since it will sink too deep into the pole and make climbing difficult. Always leave a shoulder about 1/8 in. back from the point.

Remember that climbers are for use on poles ONLY. Do not wear them while working on the ground, and do not use the gaffs for such irregular procedures as the opening of cans and the like.

Going Up

Before starting to climb a pole, there are a number of preliminary steps that should be taken. First, of course, make the preclimb inspection of equipment previously described AND PUT ON YOUR HARD HAT. Then inspect the pole to determine the best side on which to start. This is usually the back, or high side.

Get against the pole and grasp each side of it with your hands—not that you will hand-support your weight in climbing, but simply because you will use your hands to help in balancing yourself on the climbers (fig. 10-25).

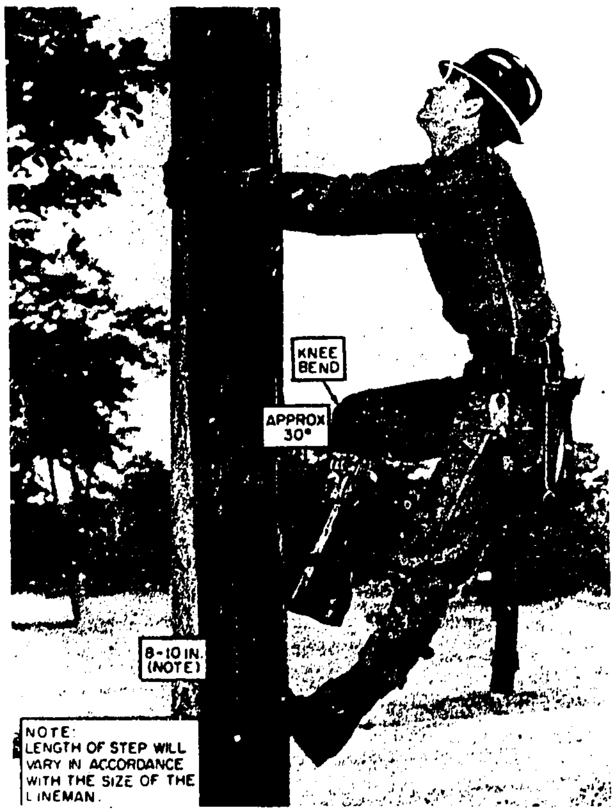
To learn pole climbing you must practice actual pole climbing. Some pointers that will help you become efficient in pole climbing in minimum time are as follows:

Raise your right leg about 8 in. off the ground and sink the gaff on that leg into the pole. Don't jab the gaff in the wood. Allow your weight to sink it in. Now, swing yourself up off the ground and lock your right leg in stiff-leg position, so that all your weight is supported on that leg.

As the next step, raise your left foot about 8 in. and sink the gaff on that foot into the wood. Then swing up onto the left leg stiff-legged, and take the next step similarly with the right foot. Continue this stepping up and locking stiff-legged until you reach working position. Keep the upper part of your body away from the pole; if you "hug" the pole, you will tend to throw the gaffs out of the wood (fig. 10-26).

At Working Position

At working position your feet should be placed so that most of your weight is on the right foot, stiff-legged. The left foot should be slightly above the right, so that the left leg is slightly bent. When you have attained this position, you must proceed immediately, with great care, to attach the safety strap.

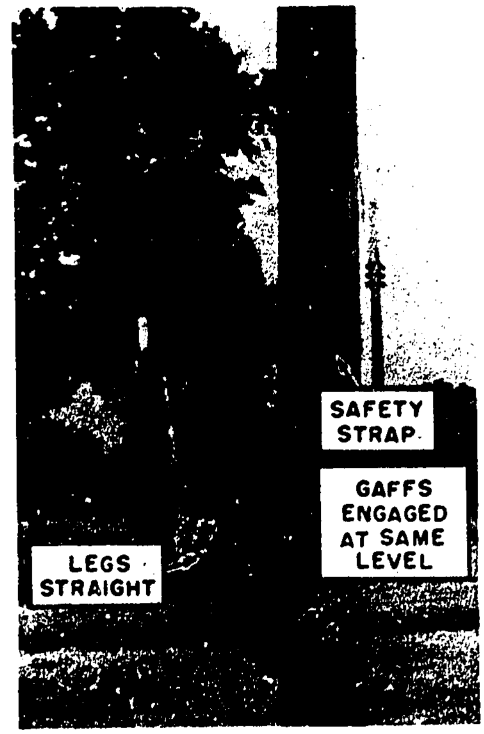


73.312
Figure 10-26.—Continuing the climb.

Crook your right arm around the pole. Use your left hand to unsnap one end of the safety strap from the left "D" ring on the body belt. Holding the end of the safety strap in your left hand, pass it around the back of the pole. Transfer the end of the safety strap from the left hand to the right hand, at the same time crooking your left arm around the pole to hold yourself in position. Then swing the end of the safety strap quickly around with your right hand and snap it onto the right D-ring on the body belt.

> WARNING: Visually check to ensure that the snap engages the D-ring. Don't depend on the sound of the keeper snapping to indicate that the snap-hook has engaged the D-ring.

You can now release your left arm gradually, so as to lean back against the safety strap (fig. 10-27).



73.313
Figure 10-27.—Working position.

Coming Down

Before you start down the pole you must release the safety belt. Crook your left arm around the pole, and unhook the safety strap from the right D-ring with the right hand. Pass the end of the safety strap to the left hand, crook your right arm around the pole, and snap the end of the safety strap to the left D-ring.

You are now ready to descend. Break out the left gaff by swinging the left knee out from the side of the pole. Step down with the left foot to a point about 12 in. below the right; stiff-leg the left leg, and bring your weight on it to sink the gaff. Then break out the right gaff by swinging the right knee away from the pole (fig. 10-28) and proceed as formerly with the left leg. Continue this stepping-down process until you have reached the ground.

Safety In Pole Climbing

Never climb an erected pole until it has been plumbed, backfilled, and tamped. Before going

73.314
Figure 10-28.—Descending.

aloft, make sure the pole can stand your weight, and carefully make the previously described inspection of body belt, safety strap, and climbers.

The body belt contains pockets for small tools. It is important to keep the tools in these pockets. Never use the center loop in the body belt for carrying a tool, however. In case of a fall, the tool may injure your tail bone.

If you try to climb with tools in your hands, your own balance on the pole will be unsafe, and you could drop tools on someone below.

The safety strap is used to secure you to the pole, leaving your hands free to work. As you go up it is always fastened to a single D-ring on the body belt. For a right-handed man it is carried on the left D-ring.

Never use an improvised safety strap, or one that has been lengthened by the addition of rope or wire. Never attach the strap to pins or to crossarm braces. Never put the safety strap around the pole above the highest crossarm if the length of pole above the crossarm is short. The strap should never be less than 1 foot below the top of the pole.

Never wear climbers except for climbing. Be careful not to gaff yourself or anybody else.

Some additional precautions to keep constantly in mind are as follows:

1. NEVER carry tools or other objects in your hand when climbing.

2. NEVER trust pins, crossarm braces, or guy wires as supports.

3. If you are working with another man on the same pole, and he goes up first, wait until he is strapped in working position before you start up.

4. Do not depend on the snapping sound when you snap the safety strap to a D-ring. Look down to ensure that the snap is engaged to the ring.

5. If the top crossarm is near the top of the pole, do not pass the strap around the short length of pole protruding above the crossarm.

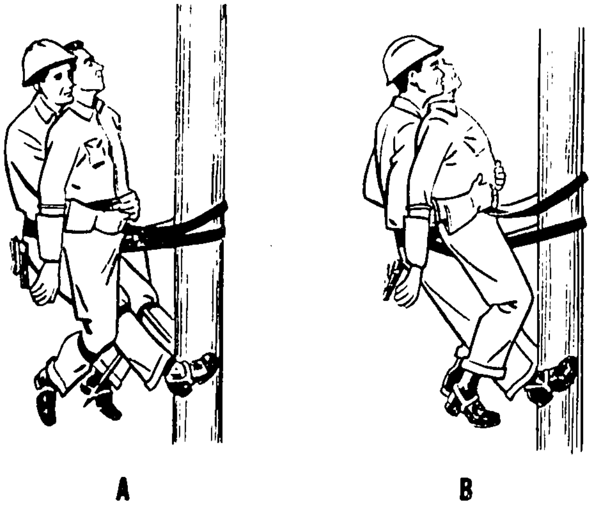
Protective Clothing and Equipment

A lineman should always wear gloves or gauntlets when tending or stringing conductors. Never work with gauntlets of the gloves turned down.

Do not wear hobnailed shoes or shoes with metal plates. When trimming trees for pole lines, wear rubbers or rubber-soled shoes for climbing. Always test safety strap and body belt before using them. Never wear a strap with stitching across it, or one mended with tape. Make all the safety checks of climbing equipment every time you prepare to go aloft.

Pole-Top Rescue

When a man working aloft is shocked into unconsciousness, there are several ways of performing "pole-top resuscitation," depending on the prevailing circumstances.



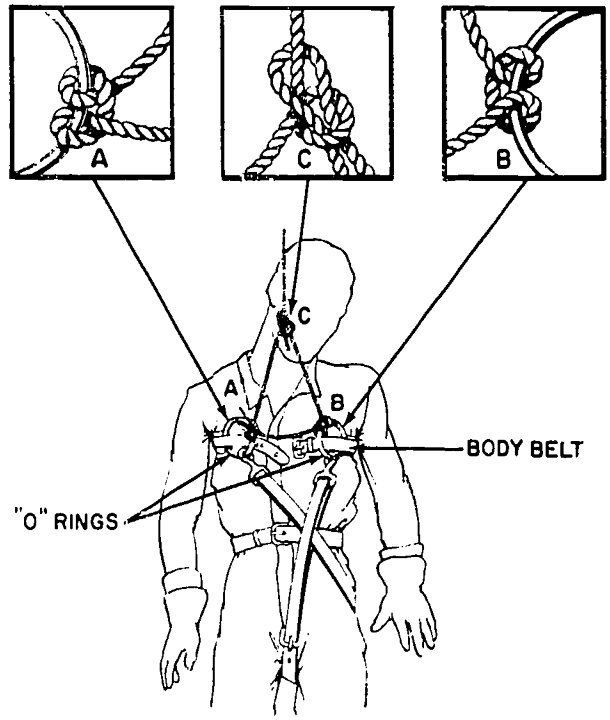
4.227
Figure 10-29.—Oesterreich method of pole-top resuscitation.

If the victim has not received severe face or nose injuries, the mouth-to-mouth method should be given in preference to other pole-top methods, because it is easier to apply, can be started more quickly, is more effective, and can be given for a longer period of time without tiring the operator. The same rules apply for this method on a pole as for on the ground.

If the mouth-to-mouth method cannot be used, the next-best alternative is the Oesterreich pole-top method. This is administered as follows. First free the victim from electrical contact, making careful use of rubber insulating equipment. Then, if possible, maneuver him into vertical position and remove his climbers.

Next take a position on the pole just below the victim's feet, and with your safety belt around the pole, climb behind the victim with your safety strap between his legs. When the strap is as high between the legs as you can get it, hold the victim in straddle position on the strap as shown in figure 10-29A.

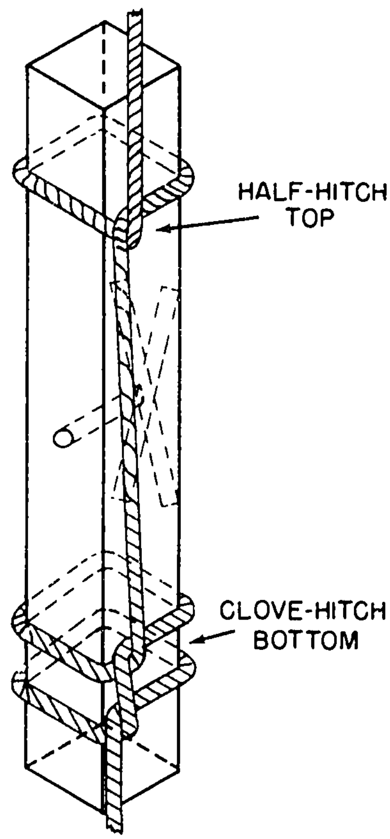
Next clear the victim's mouth of any obstructions and/or foreign matter and tilt the head back to clear the air passage. Then encircle the waist of the victim with your arms, and place both hands on his abdomen, with thumbs below the ribs and fingers touching, as shown in figure 10-29B. With your arms and hands, compress the abdomen with an upward squeezing motion. At the finish of this motion, cup your hands with the fingers depressing the abdomen just below the breastbone. Repeat this process of squeeze, pressure, and release about 12 times a minute. If the victim begins to breath, take care to keep him under control while the violent motion which usually accompanies recovering consciousness is occurring.



73.358
Figure 10-30.—Knot details of rescue hitch using a body belt and rope.

If you are the only other person (besides the victim) at the scene, inch yourself and the victim down the pole as you apply the resuscitation. After you complete each stroke, lean forward to slacken the safety belt (while still holding the victim on it) and move downward, even if you can only make an inch or two.

If others are available on the ground, have a line passed up and secure it to the victim (see fig. 10-30). Then secure a line to yourself. Both you and the victim should be lowered at the same time so you can continue to give artificial respiration.



73.75
Figure 10-31.—Crossarm, showing the proper way to fasten handline.

After a victim has revived, keep him as quiet as possible until he is breathing regularly. Have him lying down, of course. Keep him well covered and under constant close observation. Do not allow him to sit up, walk, or move until he is under regular medical care.

MOUNTING CROSSARMS AND RACKS

Crossarms are made in a variety of sizes, the size used depending on the voltage on the line and the number of conductors. For average use, a "six-pin" arm with four pins, occupied by conductors, is common. The size of this arm gives a good clearance space between condcutors.

Crossarms are sometimes mounted on a pole before the pole is raised and set in the ground. This gives the man doing the sighting an advantage. When a crossarm is mounted before the pole is set up, the crossarm through-bolt is set up tight, but the crossarm braces are left hanging loose. After the pole is set, the crossarm is leveled and the braces then attached. Finally, the through-bolt is set up hard.

If the crossarm is mounted after the pole is set, it is pulled up to a lineman in working position by a helper on the ground, using a handline attached as shown in figure 10-31. With the handline attached in this fashion the lineman can, after he inserts the through-bolt, cast off the upper half-hitch, and the helper on the ground can then heave the crossarm level.

Braces are usually fastened to a crossarm with 3/8-in. by 4-in. carriage bolts. Each brace comes down diagonally and is attached to the pole at the lower end with a 1/2-in. lag screw.

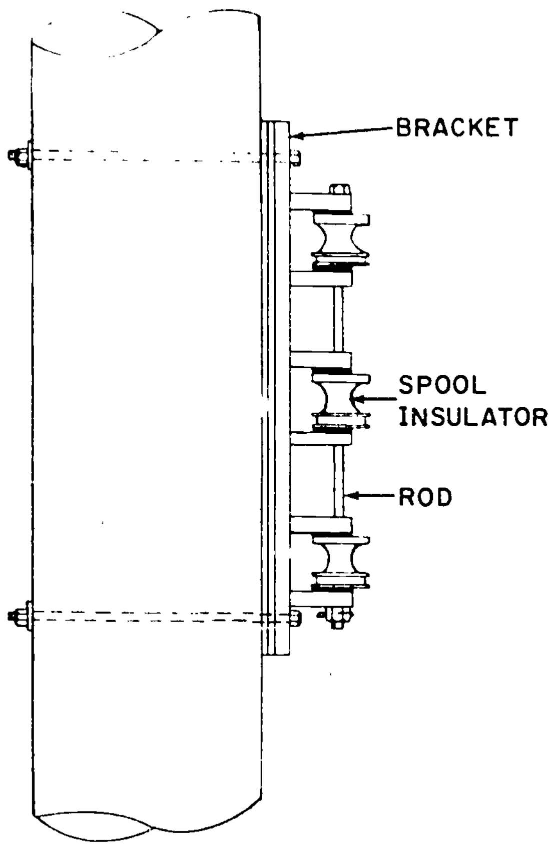
On a straight line without excessive strains, crossarms are used singly-mounted face-to-face or back-to-back, as previously mentioned. At line terminals, corners, angles, or other points of excessive strain, crossarms are doubled. Where a powerline crosses a railroad or a telephone line, crossarms should be doubled.

When double arms are used, they are fastened together at the ends with double-arm bolts. One of these is threaded all the way, and has two square washers and two nuts on each bolt between the arms. The lineman can adjust the spacing between a pair of crossarms by setting these nuts the desired distance apart on the threaded bolts.

SECONDARY RACKS

Secondary conductors may be strung on crossarms, but are usually put on secondary "racks." These racks are made in sizes to accommodate 2, 3, or 4 conductors. A secondary rack is mounted on the side of a pole (for a straight run) or on the inside of a pole (for a dead end). A rack is fastened to the pole with lag bolts on a straight line, with a through-bolt at the top and lag screw at the bottom, or with through-bolts with nuts for a dead end or where a branch line takes off from the main line. A dead end secondary rack is illustrated in figure 10-32.

Insulators are held to a rack by a rod passing through the insulators and brackets on the rack as



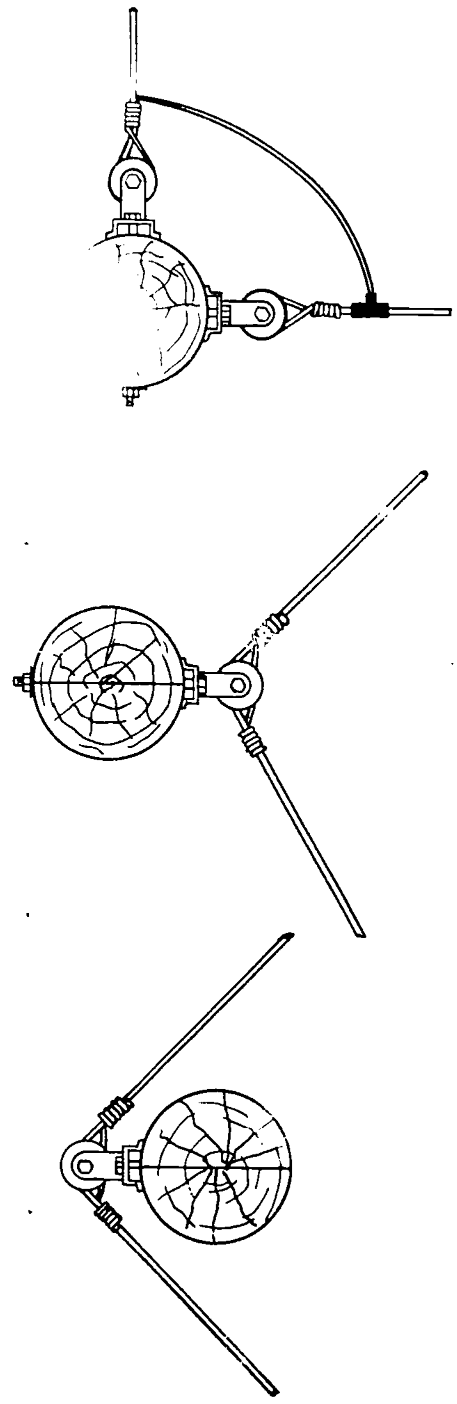
26.85
Figure 10-32.—Dead end secondary rack.

shown in figure 10-32. On a straight line or inside angle the conductor is run on the inside of the insulator. On an outside angle it is run on the outside. The conductor is always placed here with strain against the insulator. Figure 10-33 shows rack arrangements at corners and angles.

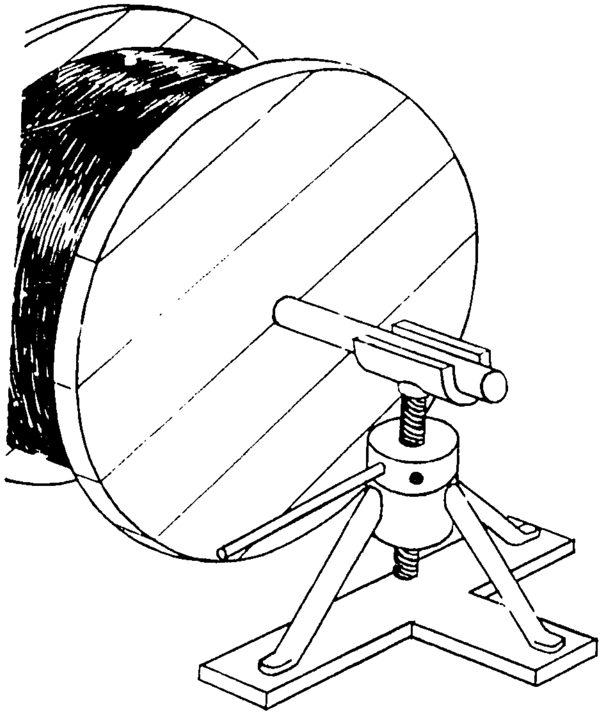
Another type of secondary construction consists of a patented bracket for holding a signal conductor. This bracket can be opened in such a way as to permit the conductor to be pulled over the insulator, which revolves like a pulley during the process. After the conductor has been pulled up to proper sag, the conductor is tied in and the bracket snapped up into vertical position.

STRINGING THE CONDUCTORS

There are various ways of stringing the conductors. One method includes placing the



73.77
Figure 10-33.—Rack arrangements at corners and angles.



73.78
Figure 10-34.—Cable reel on reel jack.

reels on a truck or trailer and driving along the line of right-of-way, unreeling the wire. This method has the advantage of not allowing the wire to drag on the ground, but in some locations you may not be able to drive a truck along the right-of-way because of rough terrain.

No matter how you string the wire, you will have to mount the reels on some support that allows them to revolve freely. This is usually done by raising a reel on cable jacks as shown in figure 10-34. A metal rod strong enough to support the reel is put through the hole in the center, and the rod and reel are jacked up on each side, with the leg of the "T" base away from the reel as shown. You may have to fasten down the bases of the jacks to keep the strain from upsetting the reel. When jacking up, it is only necessary to raise the reel just clear of the deck.

When stringing wire in rough terrain, the best method is to anchor a reel to the ground at the end of the line by means of guys run to driven stakes. A rope line is then run over the crossarms for a horizontal distance of from 1000 to 1500 ft. This line is draped on each crossarm by a lineman climbing the pole.

After the rope has been strung over the crossarms, one end is secured to the wires to be pulled, and a couple of turns taken with the other end around the winch drum on the line truck. The drum is then rotated to haul in the rope, and the wires with it. As each wire passes a crossarm, a lineman must climb the pole to set the wire in proper position and guard against twisting.

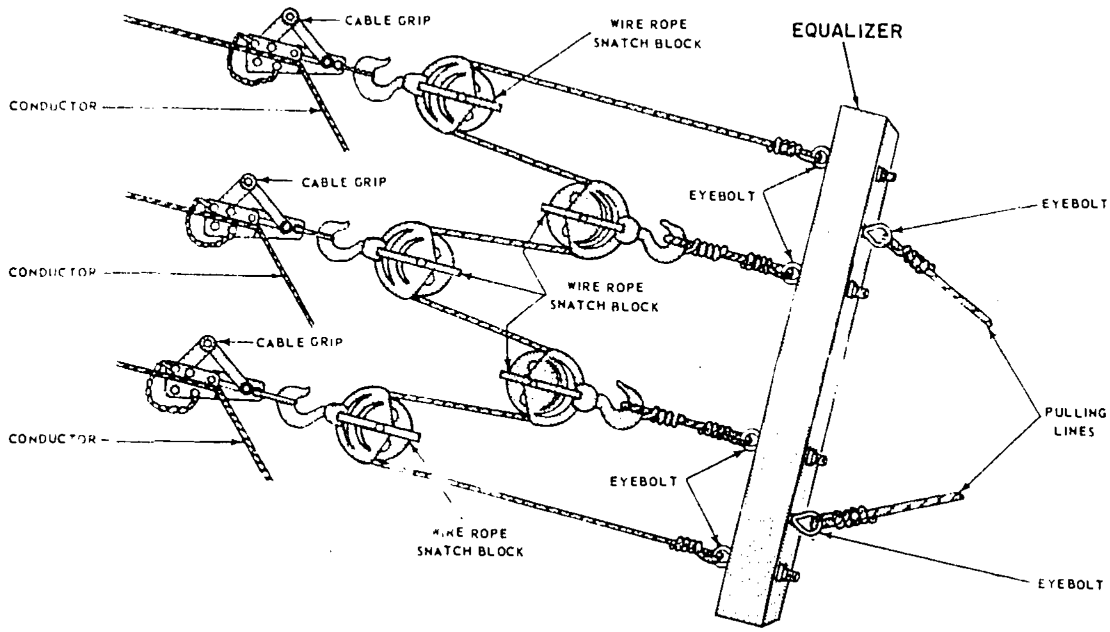
To keep a paying-out reel from revolving too fast, a brake or drage is set against the reel. This can be simply a board, held against the outer edge of the reel by a helper. As a wire or wires are being pulled, enough men must be stationed along the way to establish a chain of signal communication from the head of the line back to the line truck.

A neutral wire should always be placed on a center crossarm pin or on a pole-top pin. With a secondary rack, put the neutral wire on the top spool, so the neutral can protect the hot wires against anything that might fall from above. Putting the neutral on a center pole pin also gives the lineman a clear space around the pole to climb through—that is, it ensures that the hot wires are a considerable distance apart.

When the conductors have been hoisted in place on the crossarms and dead ended on one end, you are ready to start "pulling in"—that is, heaving on the conductors until each has been raised to proper sag. This is done with a tackle equipped with cable grips like those shown in figure 10-35. A cable grip is a clamp-type device which grips the wire tightly when a strain is applied to the grip.

When pulling two or more wires at once, it is best to use the equalizer shown in figure 10-35. This device distributes the strain equally on all the wires.

When wires have been pulled to approximately the desired sag, a lineman goes to the center span to measure the sag. Measurement at the center of each span ensures uniformity. Three common ways of measuring sag are by dynamometer, by timing vibration, and by the use of targets.



73.79

Figure 10-35.—Pulling wires with equalizer.

A lever-cam dynamometer is an instrument which is installed in the pulling line and which measures the strain of the pull. It is used in conjunction with a chart which gives the desired pull tension for a given conductor size, span length, and temperature. A traction dynamometer, also installed in the pulling line, provides direct readings on the face of the dial.

The timing-vibration process is done by striking the wire sharply near one of the pole supports, and timing by stopwatch the interval which elapses during which the impulse from the blow travels to the next pole and returns. This system is not accurate if a wind is swinging the line, or if the line is being worked on in an adjacent span.

The target-sighting method is a simple and accurate means for measuring sag. The desired sag is first ascertained from table 10-2.

Figure 10-36 illustrates the effect of temperature on the sag in a 200-ft span of 00 wire. You target-measure sag by nailing slat targets, such as a couple of pieces of wood lath, on each pole a distance below the conductor insulator equal to the desired amount of sag. A lineman then sights from one slat to the other, and the conductor is hauled up or lowered until its lowest point is on the line of sight between the slats (fig. 10-37).

After the wires are "sagged in," you allow a rest period of from 1/2-hour to 4 hours (varying according to the length of the pull), to let the wires adjust themselves to the tension in the pull. They will gradually "creep" until tension in all the spans is equalized. After they have crept to the final position you are ready to "tie in."

TYING IN CONDUCTORS

Tie wire fastens the conductor and insulator together. Conductors can be tied in various ways, but the ties shown in figure 10-38 are the ones most commonly used. Hold the tie wire tight against the insulator as you make your wraps around the insulator and the conductor wire.

In tying in wires observe the following procedures:

Always use new, fully annealed wire for ties. Hard drawn wire is brittle and cannot be pulled up against conductor and insulator.

Table 10-2.—Sag Variation With Temperature

No. (awg)	Temperature (degrees F)	Sag in inches for span lengths of					
		100 ft	125 ft	150 ft	175 ft	200 ft	250 ft
6	30	5.5	8.5	13	18.5		
	60	8	12	18	24		
	90	12	17	23.5	30		
4	30	5.5	8.5	13	18.5	25	35
	60	8	12	18	24	32	42
	90	12	17	23.5	30	39	50
2	30	5.5	8.5	13	16.5	20	29
	60	8	12	18	22	26	36
	90	12	17	23.5	28	33	44
1	30	5.5	8.5	13	15.5	28.5	24.5
	60	8	12	18	21	24	31
	90	12	17	23.5	28	31	39
0	30	5.5	8.5	13	15.5	18	23.5
	60	8	12	18	20.5	23	29
	90	12	17	23.5	27.5	29.5	36
00	30	5.5	8.5	13	15	17	21
	60	8	12	18	20	22	27
	90	12	17	23.5	26	28	34
0000	30	5.5	8.5	13	14.5	16	19
	60	8	12	18	19	21	24
	90	12	17	23.5	25	27	30

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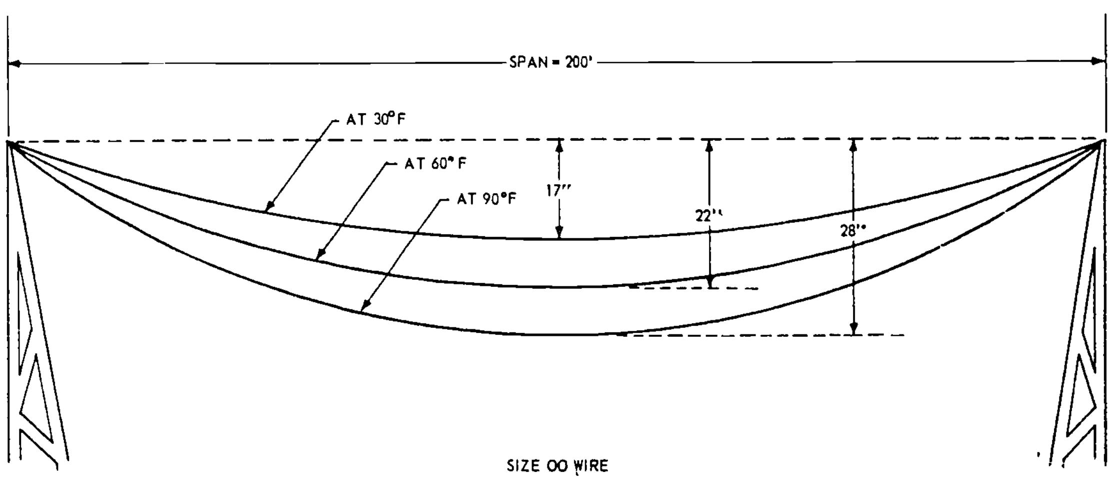

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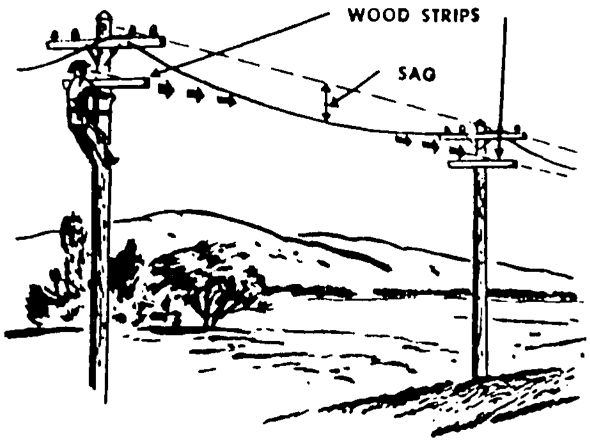
Figure 10-36.—Effect of temperature on sag in 200-ft span of 00 wire.



73.315

Figure 10-37.—Adjusting sag.

Use the proper size wire. For No. 8 bare use No. 8 bare. For No. 6 or No. 4 bare, use No. 6 bare. Use No. 4 bare for No. 2 conductor. Use No. 2 bare wire for No. 1/0 through 4/0 bare conductor.

Use a piece of tie wire that is long enough to make the complete tie, with enough left over to allow grasping. After the tie is completed, cut off the excess and form a loop or eye at the end of any projecting end of the wire.

Make positive contact between tie wire and conductor to avoid chafing and to limit possibilities of causing interference with radio communications.

INTERFERENCE ELIMINATION

Powerlines may be a source of interference with radio communications. Conductors, insulators, and hardware contribute their share by means of spark discharges, localized corona discharge, and cross modulation.

Spark discharges occur when localized excessive voltage stress exists. A conductor may become partially insulated by corrosion products or an insulator partially conductive due to cracks. A third source of stress occurs when a conductor is placed with but a small air gap between it and another metallic part of a pole.

Corona is defined as "the luminous discharge due to ionization of the air in the vicinity of a conductor when the voltage gradient exceeds a certain critical value."

Cross modulation (often the result of a corroded connection which causes non-linear rectification of currents) may occur when splices are made by twisting or serving the conductors rather than the more positive mechanical splice. Additionally, when conductors of dissimilar metals are joined, corrosion will occur unless special connectors designed for the specific combination of metals are used.

Remedies for conductor, insulator, and hardware interference are relatively simple (figs. 10-39, 10-40, and 10-41). Remember, the conditions for hardware interference are set up whenever two pieces of hardware are not securely bonded to each other or are permanently separated by too short an air gap.

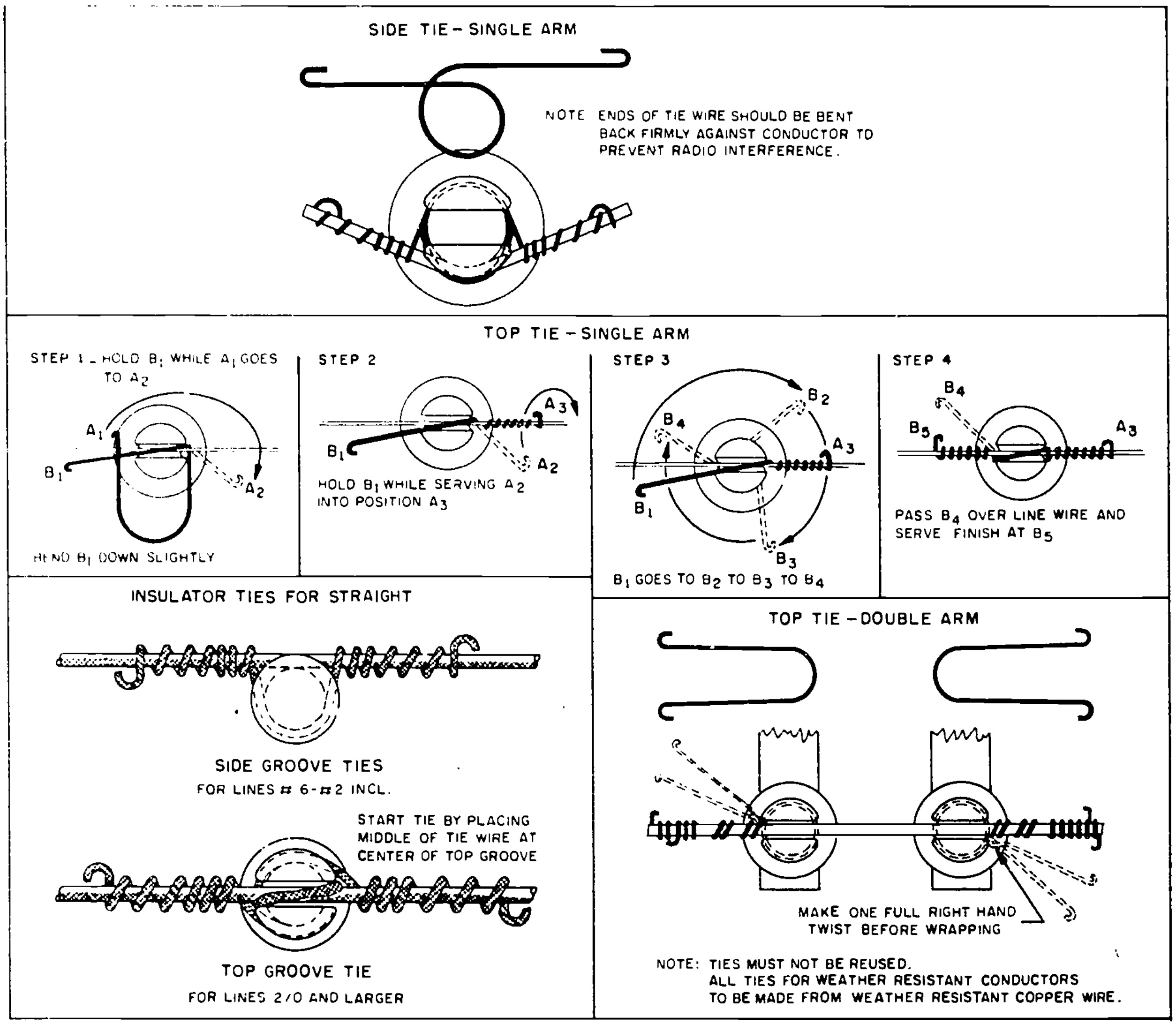
Additional specific precautions to take to minimize conductor and hardware interference include the following:

- Maintain at least 2-inch clearance through or along wood, and a 1 1/2-inch clearance through air from metal insulator pins to any other metal parts such as crossarm braces, through-bolts, square washers, molding staples, conduit, brackets for arresters and cutouts, dead end attachments, ground wires, etc.

- Permanently bond crossarm braces together on circuits greater than 5 kilovolts. Use wood crossarm braces.

- Where local electrical safety codes permit, bond metal insulator pins together on circuits above 5 kilovolts.

- Use double-coil spring washers on all bolts of attachments that support primary conductors, including primary neutral or common neutral supported on primary crossarms.
- Use ground wire clips in place of staples when attaching ground wires directly to a pole or crossarm. If metal clips are to be used on weatherproof or other types of covered ground wire, remove sufficient covering from the wire so that the metal clip will make good contact with the wire. If plastic clips are used, this procedure is not necessary.
- Ensure that ground wires, bond wires and all staples/clamps are at least 1 1/2 inches



73.316

Figure 10-38.—Tying in conductors.

from any ungrounded metal parts such as transformer brackets, crossarm braces, and throughbolts.

- Clamp bond or ground wires only against other metal parts and with a washer or locknut.

- During construction, a lag screw with or without a double-coil washer under the head should be screwed, not driven, into place for the last 1 inch of its length.

DISTRIBUTION TRANSFORMERS

For long-distance power transmission a voltage higher than that normally generated is required. A transformer is used to step up the voltage to that required for transmission. Then, at the service distribution end, the voltage must be reduced to that required for lights and equipment. Again a transformer is used, this time to step down the voltage.

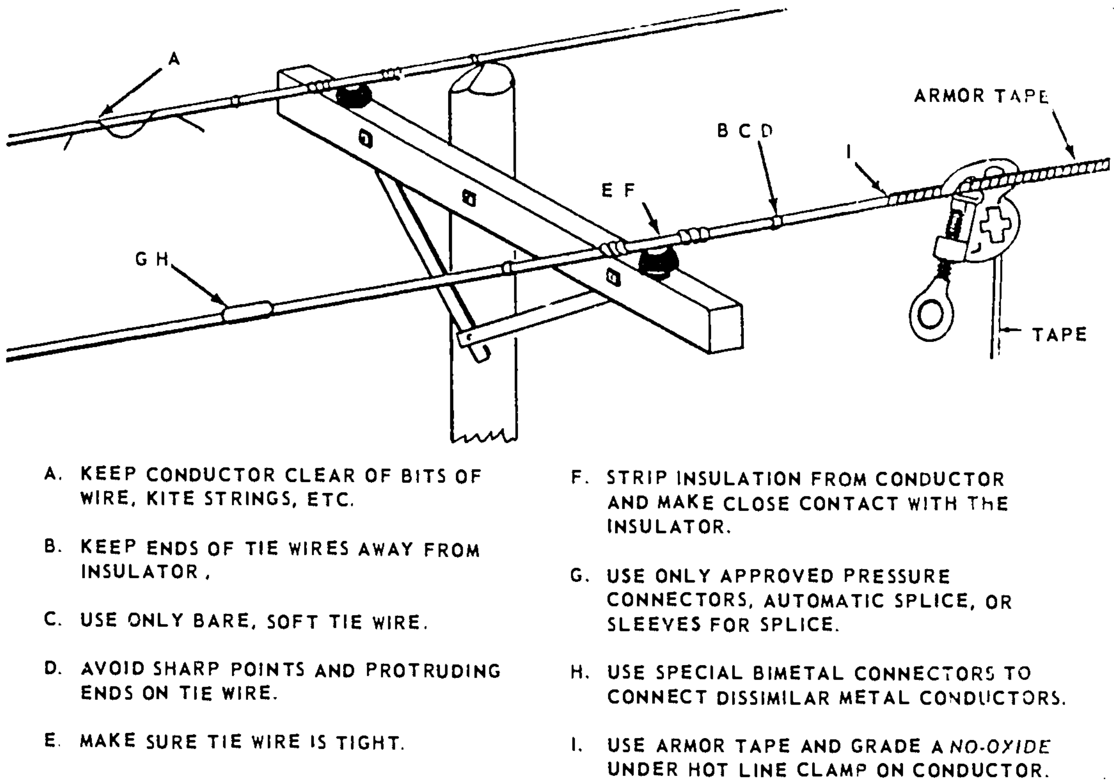


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Figure 10-39.—Corrections for common sources of conductor interference.

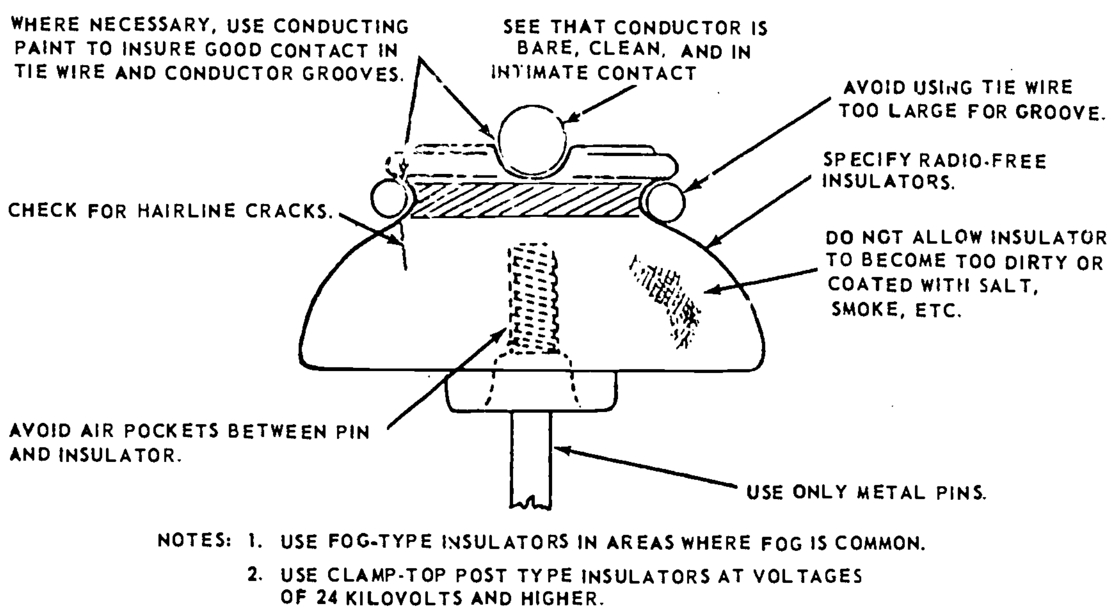
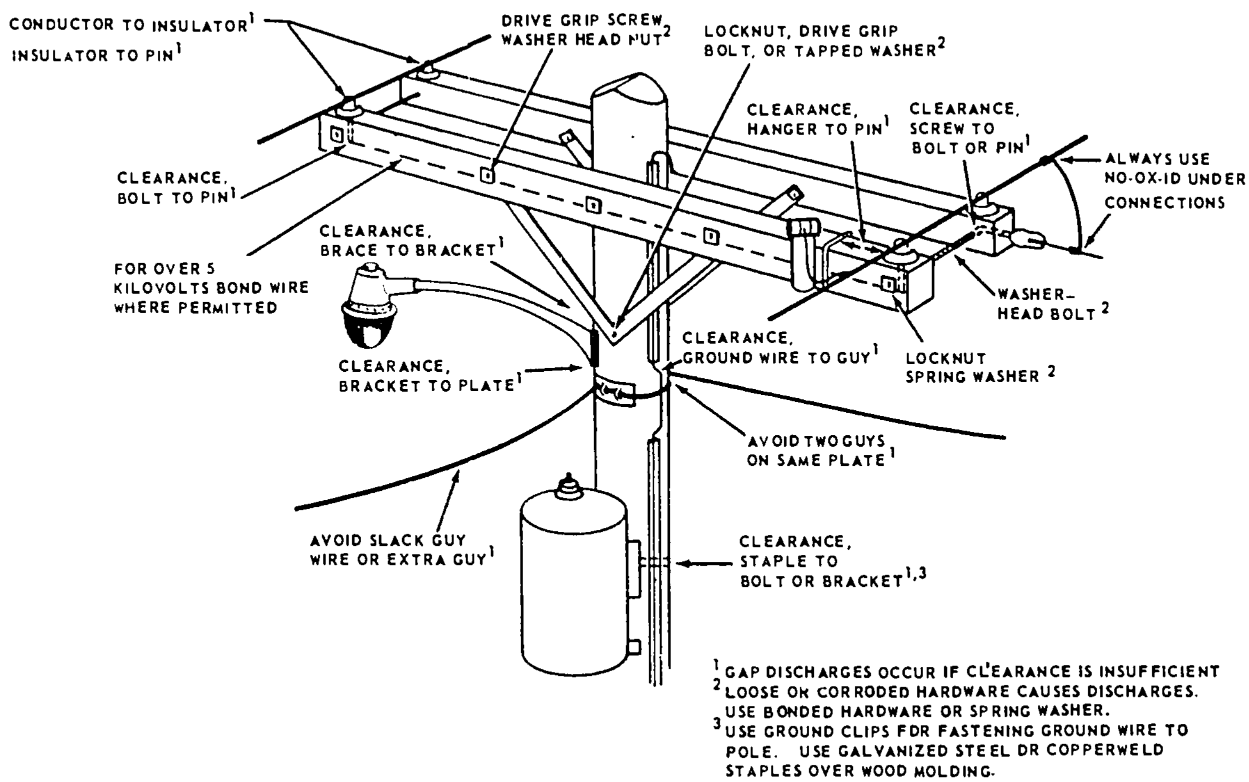


Figure 10-40.—Insulator interference corrections. 73.318



73.319

Figure 10-41.—Possible sources of hardware interference and means of prevention.

Transformer theory is explained in Basic Electricity. To the discussion given there, the following may be added.

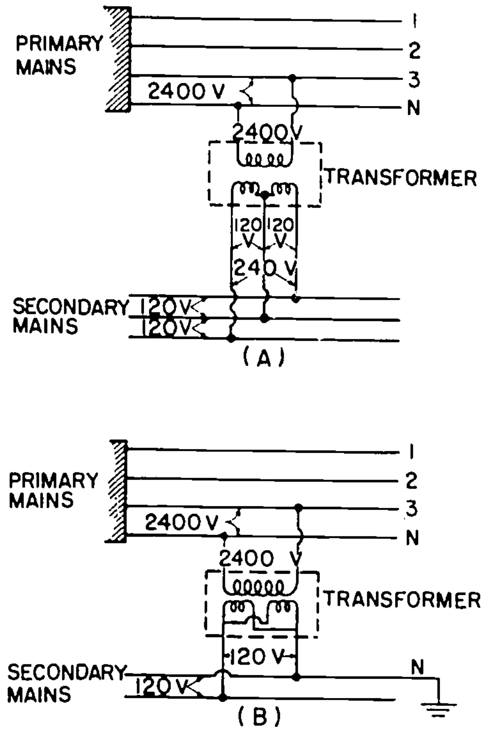
PRIMARY AND SECONDARY CONSTRUCTION

The change in voltage in a transformer depends on the number of turns of wire in the coils. The high-voltage winding is composed of many turns of relatively small wire, insulated to withstand the voltage impressed on it. The secondary winding is composed of a few turns of heavy copper wire, large enough to carry high current at a low voltage. Figure 10-42 shows a single-phase transformer, with secondary windings connected in series and parallel.

In a distribution transformer a secondary coil is wound on each leg of the laminated iron core, and the primary coil is wound over the secondary coils. The primary leads pass through a steel tank and are insulated from the tank by porcelain bushings. The secondary leads are connected to studs on a terminal block. Copper straps on the secondary terminal block permit connecting the two secondary coils in series or in parallel. From the terminal block, three secondary leads pass through porcelain bushings to the outside of the tank. An oil-level line inside the tank marks the level to which the tank is filled with transformer oil.

COOLING METHODS

There are several methods of cooling transformers, such as self air cooling, air-blast cooling, liquid-immersed self-cooling, and liquid-immersed water cooling. Self air-cooled types of transformer are simply cooled by surrounding air at atmospheric pressure, the heat being removed by natural convection (normal dissipation of heat by cooling). This type is called the dry type transformer.



73.83
Figure 10-42.—Single-phase transformer, with secondary windings connected in series and parallel.

The air-blast cooled transformer has the core and windings enclosed in a metal enclosure through which air is circulated by a blower. This type is used for large power transformers with ratings from 12,000 to 15,000 kva.

The liquid-immersed self-cooled transformer is the type previously described—that is, with coils and core completely immersed in transformer oil. In the larger sizes, the tanks are provided with external tubes or external radiators through which the oil circulates by natural convection caused by the differences in temperature in the liquid.

The liquid-immersed water-cooled transformer is sometimes used where a plentiful supply of cooling water is available. In this type, a coil of copper or brass pipe is installed near the top of the tank in the cooling oil. Water is circulated through this coil and carries away the heat from the oil as it rises in the tank.

INSULATING LIQUIDS

Insulating liquids have high insulating quality and serve two purposes: First, they insulate the coil; and second, they help dissipate the heat generated by the resistance of the windings and eddy currents in the iron core. If this heat were not removed, the transformer would operate at excessively high temperature, which in turn would damage or destroy the insulation on the coils.

Two common types of insulating liquids are mineral oil and Askarel.

Mineral oil is a nontoxic insulating liquid. It is used in different types of high-voltage electrical equipment, such as circuit breakers, switches, and transformers. Mineral oil must be kept in an airtight container, or else sludge will form. This sludge will settle in the bottom of the tank and slow the natural transfer of heat. Also the longer mineral oil is left exposed to air, the greater is the loss of insulation properties.

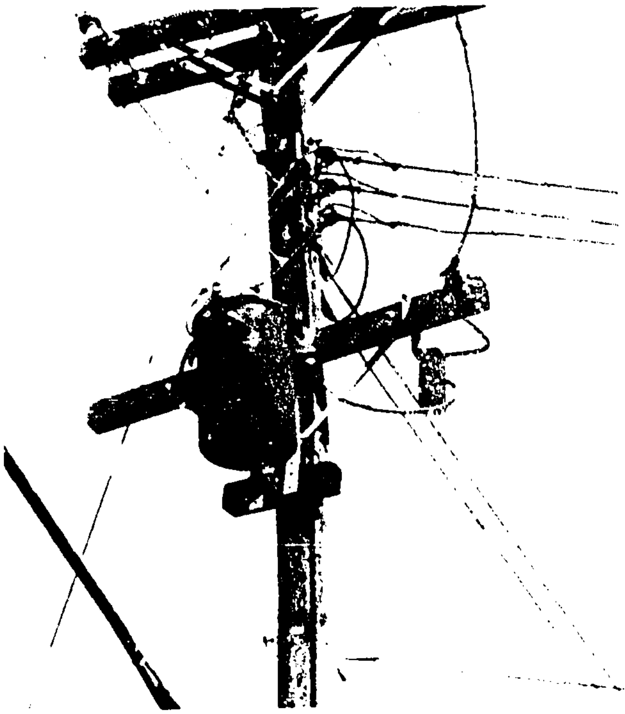
Askarel is a synthetic, nonflammable insulating liquid. It has several trade names such as Pyranol, Inerteen, Chlorextrol and Asbestol. This liquid must be handled with care because of its toxic chemical properties. Askarel is used in special transformers for applications where flammable liquids must be avoided.

Askarel may have an irritating effect upon the skin, eyes, nose, and lips. It may irritate skin abrasions or tender parts between fingers.

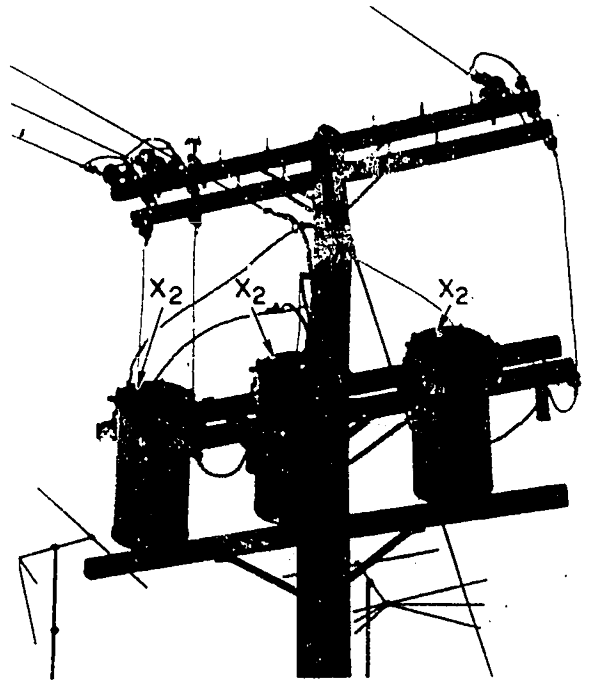
To protect yourself when handling Askarel, apply castor oil or approved protective cream to the face and hands. Also wear splashproof goggles. In case the liquid comes in contact with the skin, wash thoroughly with warm water and soap.

Ensure that the work space is properly ventilated before working on transformers containing Askarel.

Avoid breathing Askarel vapors. A full stomach will reduce any tendency toward nausea in the event Askarel vapors are inhaled. Make sure you eat before handling Askarel. If a job is lengthy, you should eat every 2 or 3 hours.



73.86
Figure 10-43.—Single transformer hung with crossarm brackets.



26.82
Figure 10-44.—Three-phase bank of transformers hung on crossarm.

TRANSFORMER MOUNTING

Transformers are mounted on poles in various ways, such as suspended on a bracket bolted to the pole; suspended from a crossarm with brackets; or set on a platform mounted on an H-frame.

Single-phase transformers are usually hung with a through-bolt type bracket or a crossarm type bracket. Figure 10-43 shows a single transformer hung with crossarm brackets. Fig. 10-44 shows a bank of three transformers of 25-kva capacity hung the same way.

Formerly, all banks of three transformers were hung with crossarm brackets or mounted on a platform between two poles. Because of improved materials, however, transformer capacities have been enlarged without increasing their size and weight. This means that banks of three large transformers can now be hung on a pole with a through-bolt bracket type suspension, as shown in figure 10-45.

The old method of mounting transformers on a platform required an extra pole and the added cost of building the platform. This method is still used when installing large transformers and in special job applications. Figure 10-46 shows the platform method of mounting a bank of three single-phase, 25 kva transformers, Y-connected to obtain single-phase and three-phase power.

TRANSFORMER LOAD

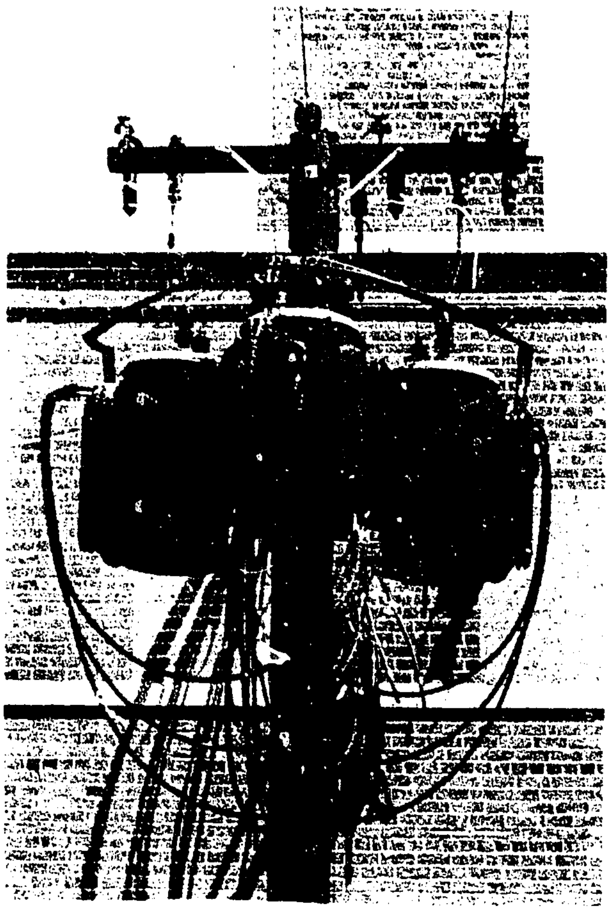
Most transformers are rated according to the kva load the transformer can carry without developing a temperature rise of more than 55°C (about 131°F), given the following conditions:

1. The transformer is operating at the rated voltage, or not in excess of 105 percent of the rated voltage.

2. The transformer is operating at the rated frequency.

3. The temperature of the surrounding air at no time exceeds 40°C (104°F), and the average during any 24-hour period does not exceed 30°C (86°F).

The 55°C allowable temperature rise is a common standard; however, the nameplate of a



73.88

Figure 10-45.—Three 37.5-kva transformers mounted with through-bolt type brackets.

particular transformer may indicate a different standard.

The proper loading of a transformer also depends on the balancing of the load on the distribution conductors. This balancing should be checked periodically with a clamp-on ammeter, to ensure that the circuit is correctly balanced. You may at times have to shift some of the load from one phase to another to keep the load balanced in the transformer.

When current is being supplied to a motor by a transformer, the kva rating of the transformer should be at least as high as the hp rating of the motor—meaning that a (for example) 75-hp motor would require a 75 kva transformer. Transformers for small motors should have a somewhat larger kva capacity than the motor kva capacity if the motors are to be run at full load or slight overload most of the time. Power input to the primary coil of a transformer is practically equal to output—meaning that the power factor is close to 1.00. However, there may be small losses, in which case P will again equal, not the product of E time I, but the product of E times I times a power factor of less than 1.00.

GROUNDING TRANSFORMERS

Grounding of a distribution system helps to prevent accidents to personnel and damage to property in the event of insulation breakdown, accidental shorting of high- and low-voltage lines, or a lightning strike.

If a high-voltage line is accidentally shorted with a low-voltage line, the current will flow through the secondary coil of the transformer to the secondary ground, which will in turn cause the primary protective device to open the circuit. In this case the primary protective device which functions is the substation circuit breaker. An accidental shorting of the primary and secondary windings in the transformer will cause the primary fuse, ahead of the transformer, to open.

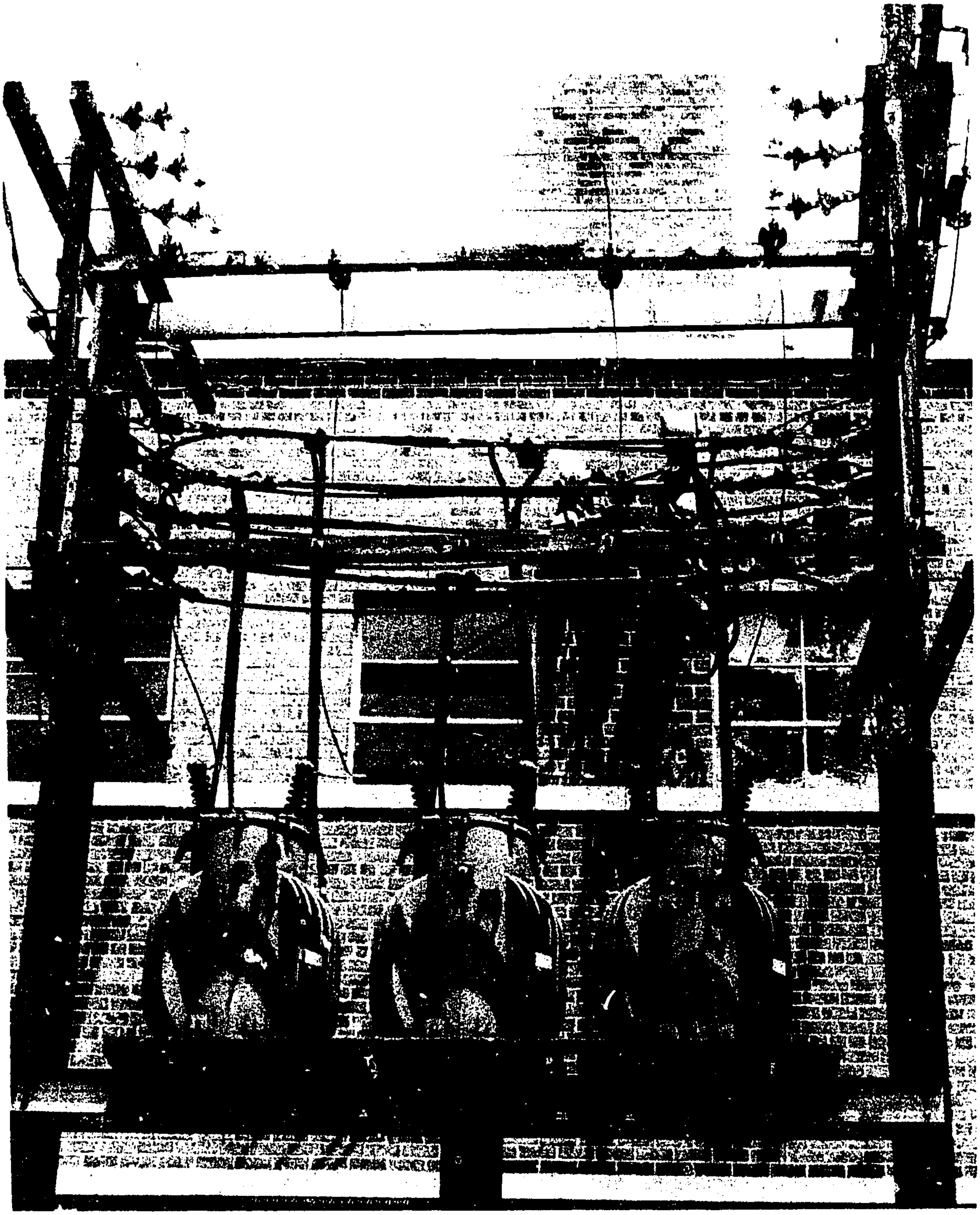
If, however, there are no ground connections, the primary voltage will be impressed on the secondary conductors, which are usually insulated for 600 volts, and considerable damage to equipment will occur. Great danger will exist for anyone touching any electrical equipment at the time.

Ground resistance must not exceed 25 ohms to ground. This resistance can be measured with various portable ground testing instruments, such as a megger. One procedure for measuring ground resistance with a megger is shown in figure 10-47.

Where ground resistance is too high, it may be lowered by one of the following methods:

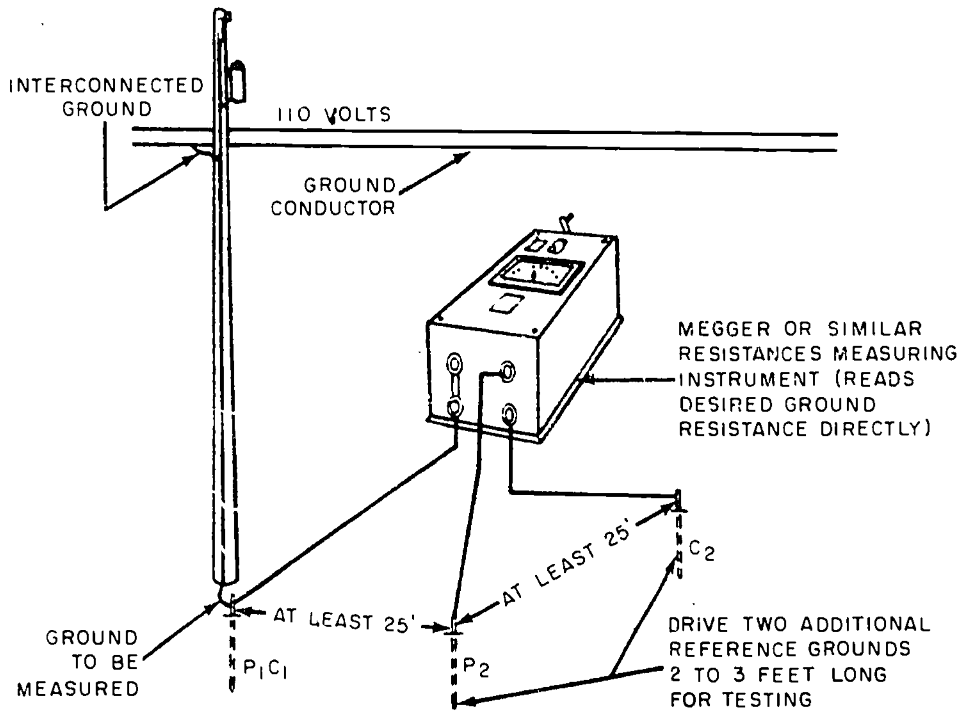
1. Driving additional rods, spacing them 6 feet apart, and then connecting them in parallel.

2. Larger rods are effective where low resistance soils are too far below the surface to be reached by ordinary length rods.



65.62

Figure 10-46.— Three single-phase 25-kva transformers moun   on H-frame platform.



73.359

Figure 10-47.—Measuring ground resistance where ground wire is interconnected with grounded distribution neutral conductor.

3. The treating soil method is advantageous where long rods are impractical because of rock and other obstructions. Copperclad ground rods or 1/4-inch copper plating may be used for grounds to be treated because the heavy copper exterior resists the corrosive conditions caused by treating chemicals. Common rock salt, copper sulphate, or magnesium sulphate are used for treating the ground. These are placed on top of the soil and not in direct contact with the rod (see fig. 10-48).

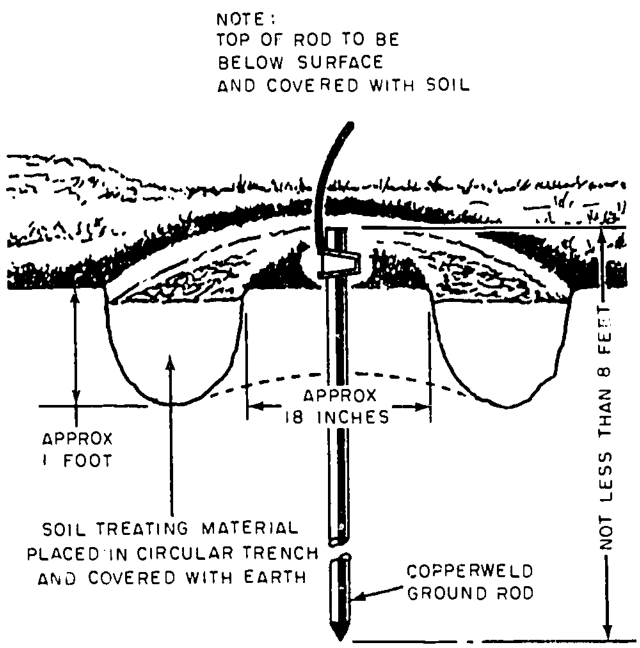
4. A combination of the above methods may be necessary and advantageous at times.

The installation of a single driven ground rod is shown in figure 10-49. The ground wire is placed on the side of the pole subject to least damage from traffic. This wire must be properly insulated from the pole line hardware where possible. The wire must also be covered with molding along the underside of the crossarm where it passes other wires on a pole and for a distance of at least 6 feet below and 4 feet above the wires. It must be covered to a point 8 feet above the base of a pole and insulated where it passes all strain guys.

TRANSFORMER POLARITY

All transformers carry standard polarity markings. The letter "H" is used to indicate the high-voltage terminals, and the letter "X" to indicate the secondary terminals. The extreme right-hand lead as you face the high-voltage side of the transformer is marked "H1," the next is marked "H2," and so on. The secondary terminals, "X1," "X2," and so on, may be in numerical order or reverse order.

Transformer polarity is important only when transformers are connected paralled for single-phase operation or are used to supply three-phase service. Figure 10-50 shows the lead markings of single-phase transformers with additive and subtractive polarity. Figure 10-51 show how to test for polarity if the nameplate is missing.



73.360
Figure 10-48.—Treating grounds.

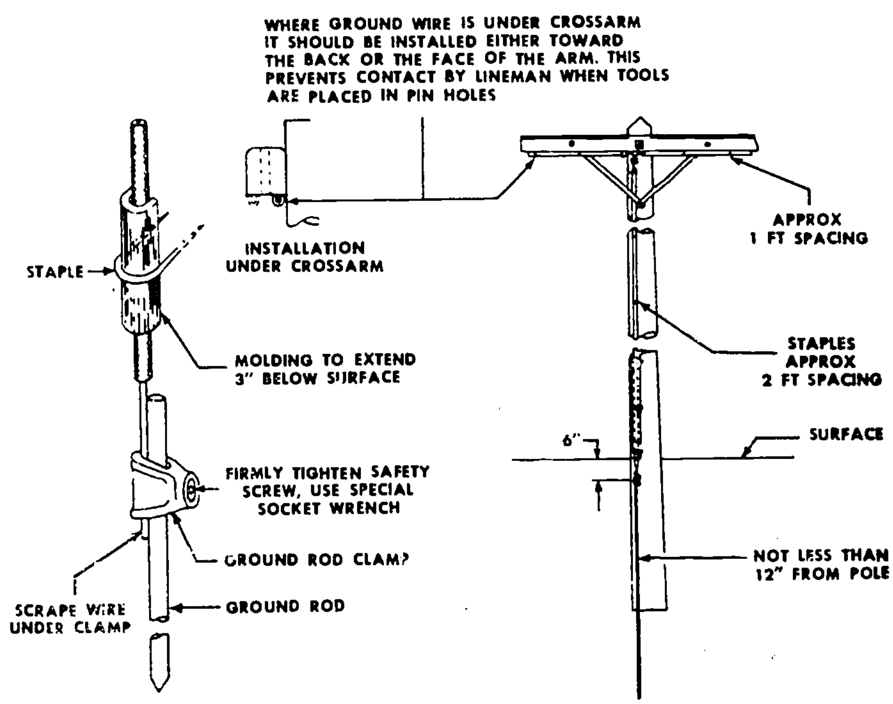
CAUTION: When making such tests, voltage must not be applied across the secondary side of the transformer because the primary voltage would then be equal to the applied secondary voltage multiplied by the transformer turns ratio. This voltage would be dangerously high to personnel and damage the voltmeter.

TRANSFORMER CONNECTIONS

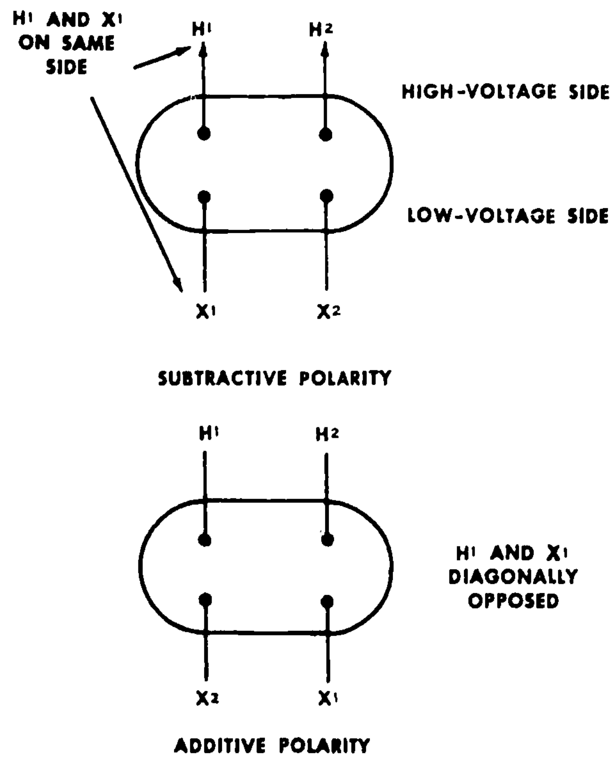
Transformers are commonly connected for three-phase service by either "delta" connection or Y-connection (also called star connection).

Delta connection (fig. 10-52) is made by connecting adjacent terminals of the the transformers. The right lead of one winding is connected to the left lead of the next winding. Coil voltage equals phase-to-phase voltage of the line. Coil current equals line current in each phase wire divided by 1.73.

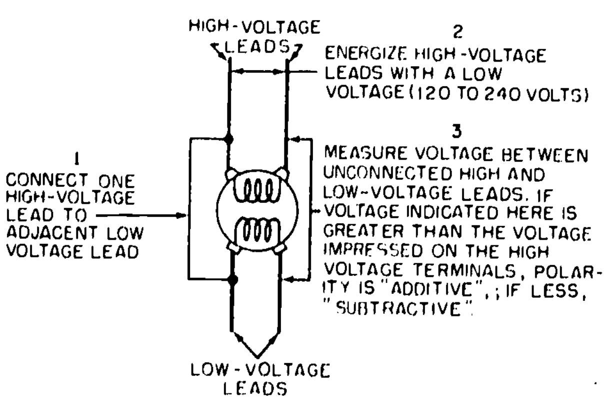
Y-connection (fig. 10-53) is made by connecting the three right (or the three left) leads to a common neutral. The three left (or right) leads are connected to phase wires of the lines.



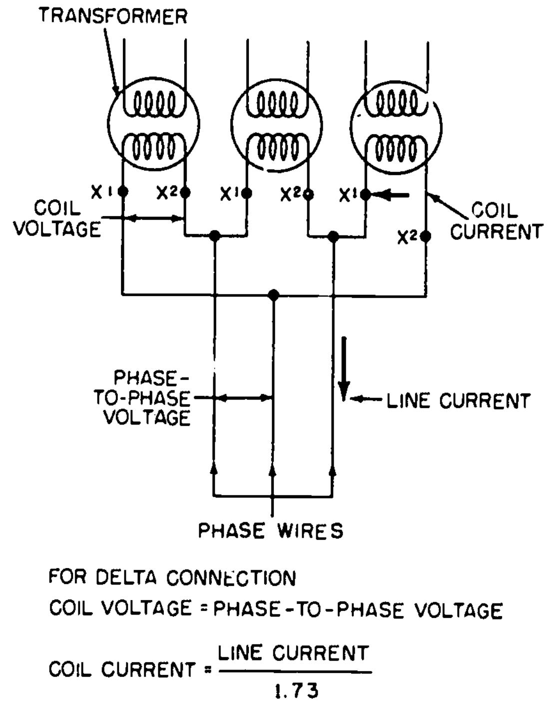
73.361
Figure 10-49.—Ground-rod installation for single driven ground.



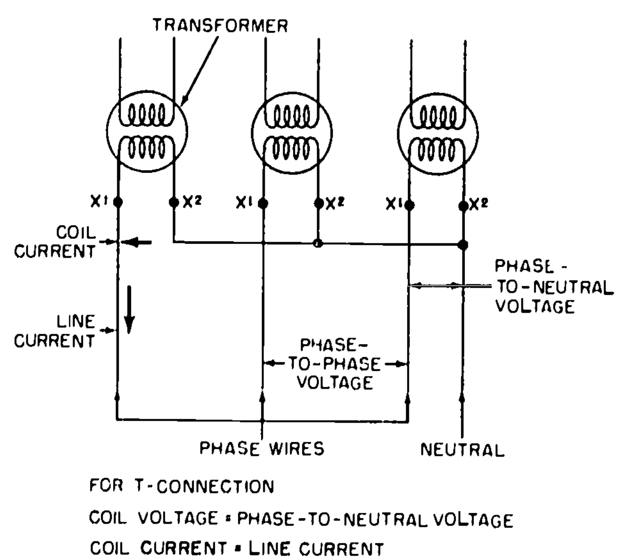
73.84
Figure 10-50.—Lead markings of single-phase transformer.



73.85
Figure 10-51.—Test for transformer polarity.



73.92
Figure 10-52.—Delta connection.



73.93
Figure 10-53.—Y-connection.

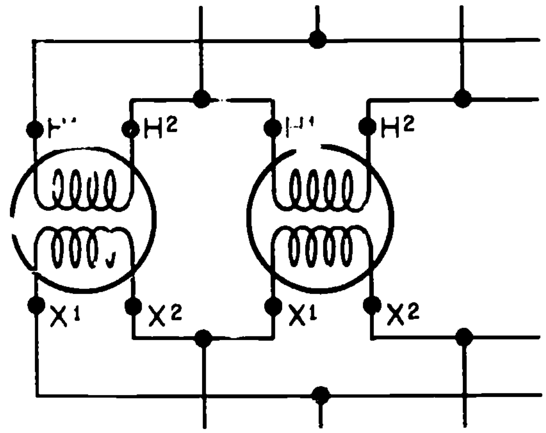
Coil current equals line current in each phase wire. Thus, if three 2400-volt transformers are Y-connected to a circuit which measures 2400-volts from phase-to-neutral or 4160 volts from phase to phase, coil voltage is 2400 volts.

Three single-phase transformers connected to a three-phase circuit are called a transformer "bank." Connections are made with combinations of delta connections and Y-connections, some of which are as follows:

A bank of transformers is "delta-delta-connected" when the primary windings and the secondary windings are both connected in delta (fig. 10-54).

In an "open-delta" connection (fig. 10-55) one of the three transformers in a delta-delta bank is disconnected because of failure. This converts the delta-delta connection to "open-delta" connection for emergency operation. The open-delta connection delivers three-phase power using only two single-phase transformers. The removal of one of the three transformers reduces the capacity of the bank, not to 66 2/3 percent of the original capacity as one might expect (100 percent minus 33 1/3 percent), but to 58 percent of the original capacity.

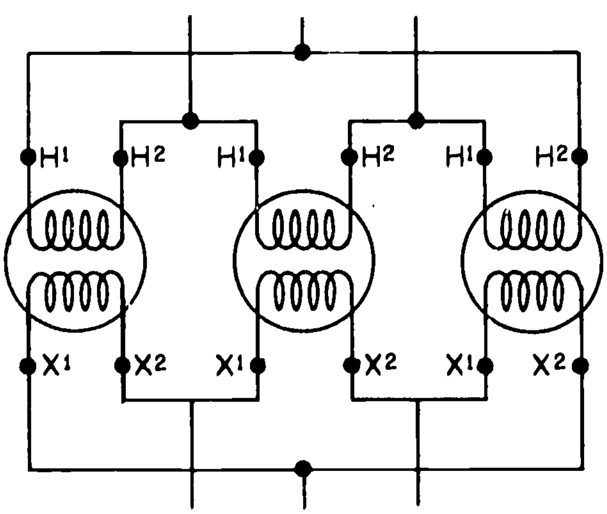
A bank of transformers is "Y-delta connected" when the three primary windings are Y-connected and the three secondary windings delta-connected (fig. 10-56). This permits the use of a primary voltage of 4160 volts with an output of 240 volts. Actually the primary voltage of each transformer is 2400 volts, as shown in figure 10-56.



73.95

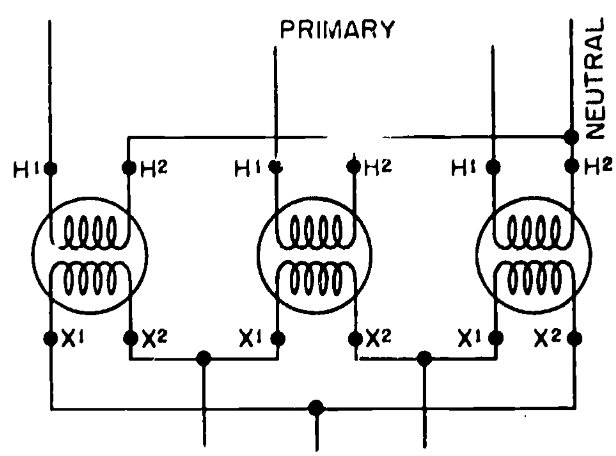
Figure 10-55.—Open-delta connection.

A bank of transformers is "delta-Y-connected" when the three primary windings are delta-connected and the three secondary windings Y-connected (fig. 10-57). By Y-connecting the secondary, you can take care of three-phase power and single-phase lighting from the same transformer bank. The single-phase



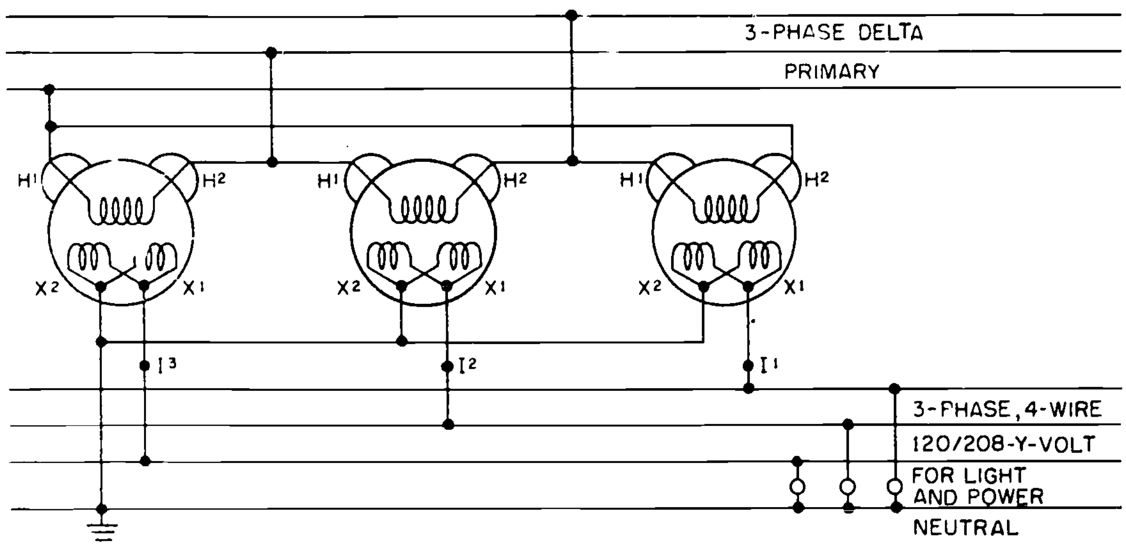
73.94

Figure 10-54.—Delta-delta connection.



73.96

Figure 10-56.—Y-delta connection.

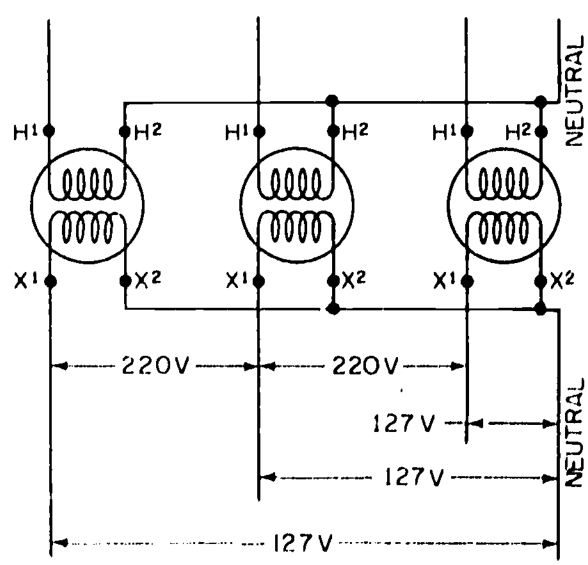


26.87

Figure 10-57.—Delta-Y connection.

load is evenly distributed by using the neutral wire and alternate lines. You can supply a 110-volt single-phase lighting system from a delta-delta connected bank of transformers by grounding the midtap of one of the transformers; however, this is a disadvantage in that it puts the entire lighting load on one transformer.

A bank of transformers is "Y-Y-connected" (fig. 10-58) when both primary and secondary windings are Y-connected. Because the arrangement is one which causes inductive disturbance, it is seldom used.



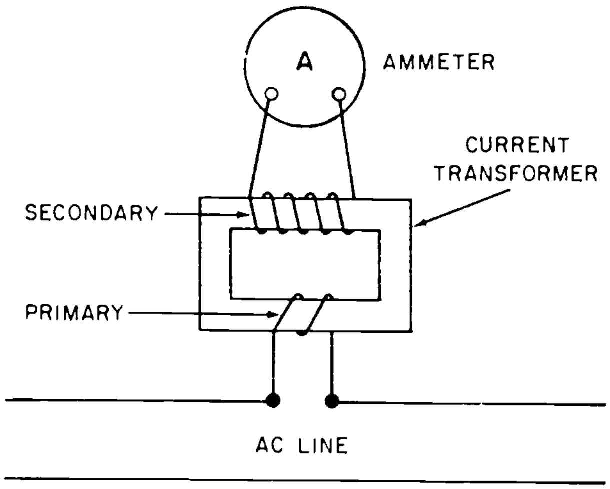
73.98

Figure 10-58.—Y—Y connection.

CURRENT TRANSFORMERS

When a large alternating current is to be measured, the ammeter is not connected into the line but, instead, is connected into the circuit through a current transformer (see fig. 10-59). Information on current transformers is given in Basic Electricity, NAVPERS 10086-B. If necessary, review material on current transformers in chapter 15 of Basic Electricity before going on to the next chapter of this manual.

Standard practice today is to design all current transformers so that 5 amperes will be flowing in the secondary when full load current



73.362
Figure 10-59.—Current transformer.

is flowing in the primary. For example, a transformer designed for 1,000 amperes in its primary would supply only 5 amperes to an ammeter in its secondary as its full load of 1,000 amperes. Such a transformer would have a ratio of 1,000 to 5 or 200 to 1.

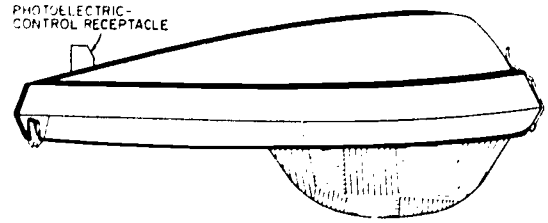
Current transformers are also used to supply current to overload trip coils of oil switches, to current coils of wattmeters, and to protective relays of all kinds.

CAUTION: Never open the secondary of a current transformer without shorting it before removing a meter. Extremely high voltage will develop if the secondary is opened.

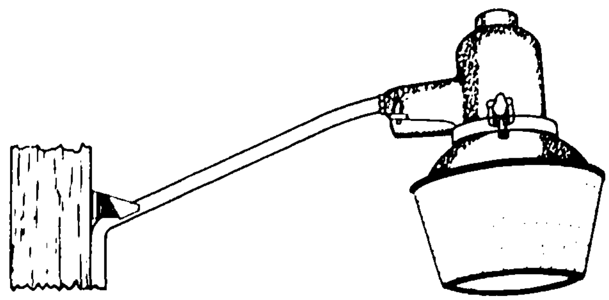
STREET LIGHTING FIXTURES

A street-lighting fixture includes a bracket or post for mounting. The mounting bracket for an overhead light usually consists of a metal pipe or framework with a pole-mounting fitting at one end and luminaire at the other (fig. 10-60). An "upsweep bracket" type of fixture is shown in figure 10-61.

CAUTION: To prevent fragmented glass from entering your eye, when replacing a defective lamp, keep your eye level above that of the lamp.



73.265
Figure 10-60.—Common type of exterior lighting fixture.



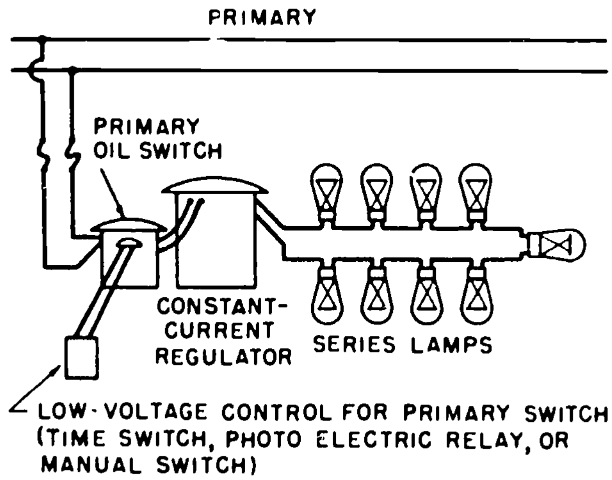
73.266
Figure 10-61.—Upsweep-bracket fixture.

STREET LIGHTING CIRCUITS

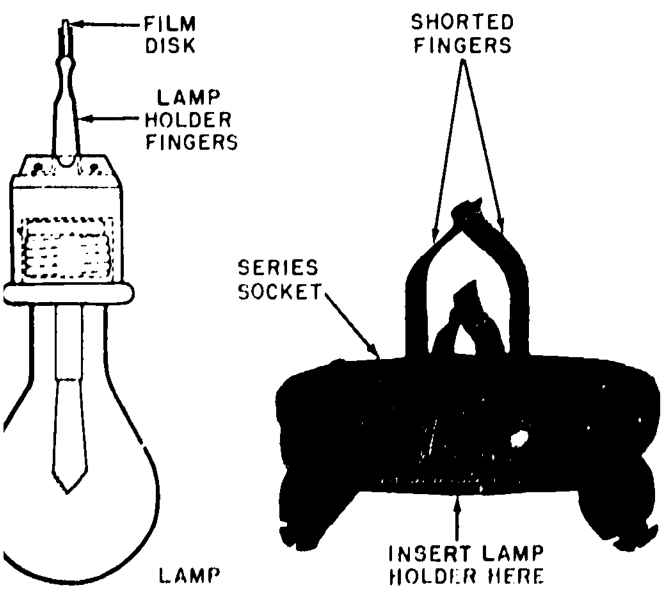
A "series" outdoor lighting circuit (fig. 10-62) is supplied by a regulating transformer which gives a uniform current, usually of 6.6 amperes, to the street lights in the circuit. Insulating transformers or autotransformers are available for stepping up the current to 15 or 20 amperes. The higher amperage permits more rugged lamp filaments, which give longer life for lamps of equal candlepower and higher lamp efficiency.

The series circuit is easily controlled, but any break interrupts the entire circuit. A film-disk cutout, along with a special lamp holder and socket (fig. 10-63), will prevent lamp failures from interrupting the circuit.

With the lamp operating, the current passes from one finger through the lamp and out the other finger. When a lamp fails, the series circuit is opened and the quarter-like film disk (between



73.262
Figure 10-62.—Series street-lighting circuit.



73.322
Figure 10-63.—Series lamp, socket, and film disk.

the lamp holder fingers) is punctured. This allows current to pass from one finger through the punctured film disk, and then to the other finger—thus completing the circuit. The socket is so made that when the lamp holder is removed the fingers are short-circuited, keeping the series circuit completed.

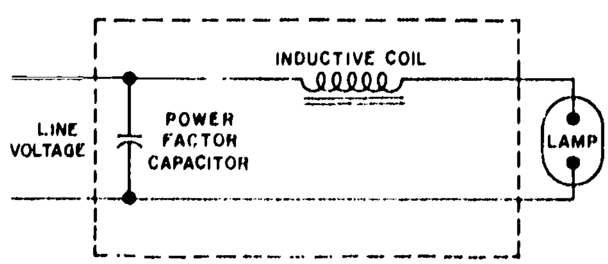
CAUTION: Do not reuse punctured film disk cutouts or substitute tape or paper for a film disk cutout.

When mercury vapor lamps are used in street lighting, a ballast or transformer is required to produce the higher voltages necessary to operate these lamps. This system is generally used in new construction because of its low maintenance cost and longer life.

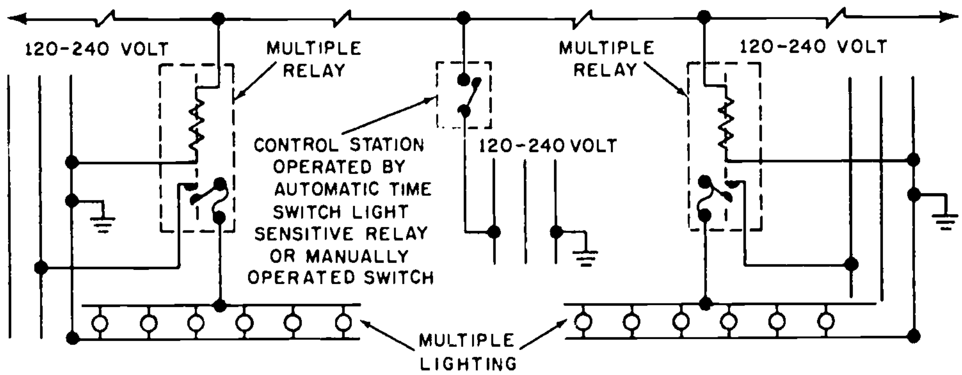
Mercury vapor lamps have a quartz arc tube, which contains a small quantity of mercury and a starting gas—argon. The lamps have a negative characteristic, and therefore require a ballast for proper operation. With no ballast the current to the lamp would increase until the lamp was destroyed. The ballast actually has three functions: 1) to limit current to the lamp; 2) to provide sufficient open circuit voltage to start the lamp; and 3) to match available line voltages to lamp operating voltage.

A simple mercury ballast is shown in figure 10-64. This ballast has an inductive choke coil in series with the lamp. Since this circuit is highly inductive, a low power factor of approximately 50% is obtained. The power factor may be corrected with a capacitor as shown.

A "multiple" street lighting circuit consists of a number of street lights delivering a low voltage on a secondary main. However, running secondary conductors any great distance to supply a lamp or group of lamps is impractical because of the excessive voltage drop. Figure 10-65 is an example of a multiple lighting system having a pilot control circuit.



73.333
Figure 10-64.—Mercury ballast.



73.364

Figure 10-65.—Pilot circuit energized at night, extended to control multiple relays or oil switches.

The pilot circuit will turn all lights on at the same time through the use of local relays. The power needed to supply the lighting comes from local sources.

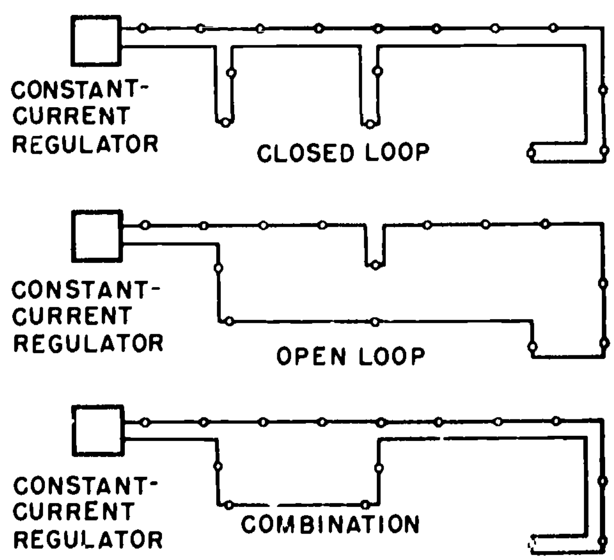
INSTALLING LIGHTING CIRCUITS

A series circuit may be installed with the return wire on the same pole or it may follow a different route. These are known as closed loop and open loop circuits (fig. 10-66). A series circuit may be installed on the same cross-arm with the primary-distribution conductors (fig. 10-67). If two primary crossarms are necessary, the streetlight wires should be carried on the lower arm in the end-pin position. If two separate single-conductor street circuits are on the same lead, they should not be placed in adjacent pin positions because it would cause confusion in troubleshooting.

The constant-current regulator may be of the indoor or outdoor type. Most installations have outdoor regulators. The main types of installation used for these regulators are platform- or single pole-mounted. Note that any regulator larger than 20 kva should be on a platform. A single pole mounting and wiring diagram is shown in figure 10-68.

TROUBLESHOOTING

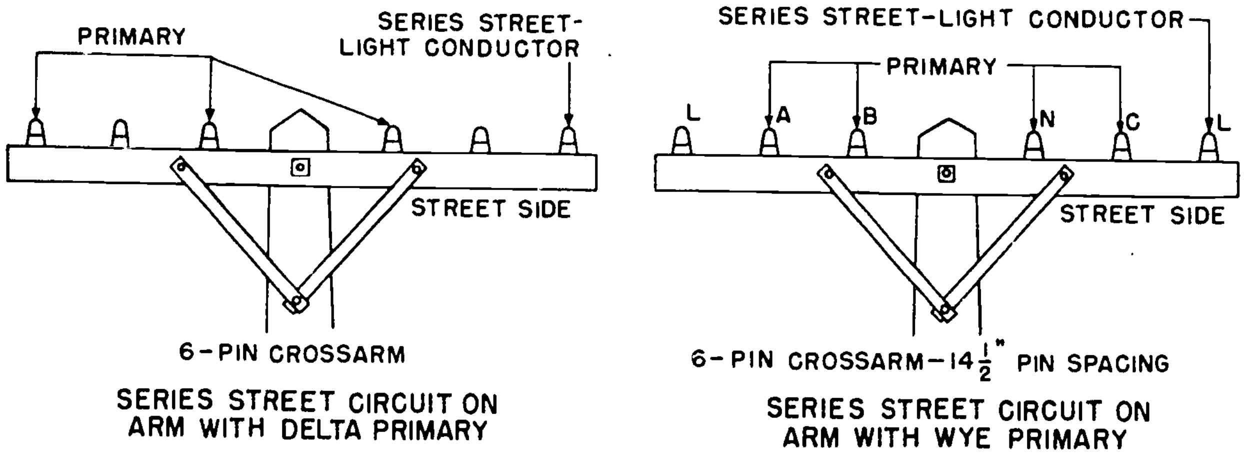
A series circuit produces many more operating problems than a small multiple circuit



73.263

Figure 10-66.--Closed and open loops in series circuits.

because of the many devices involved, and because any open in a series circuit interrupts the entire circuit. The most common and most troublesome fault is failure of all lamps in the circuit. Troubleshooting with the circuit energized gives quickest results, but personnel must be qualified for such work and use all standard safety equipment and practices. When the circuit covers a small area, check for fallen wires,



73.264

Figure 10-67.—Series circuit on same crossarm with primary distribution system.

grounds, and the like, before any sectionalizing procedures are attempted. When the circuit covers a large area, sectionalize before checking. Table 10-3 lists the various types of trouble likely to occur and gives their possible causes.

SECTIONALIZING

By locating trouble with the regulator energized you can trace the fault to a small portion of the circuit. Every electrical foreman should have a diagram for use in sectionalizing. Sectionalizing procedures for closed- and open-loop series energized circuits are as follows:

1. Closed Loop. Short circuit (jumper) both conductors near the middle portion of the circuit.

a. If lamps toward the regulator light up, open must exist in remaining portion.

(1) Divide this open portion in half and jumper it again, leaving the first jumper on.

(2) Lift the first jumper so a 1-inch gap exists. If excessive arc continues, it indicates an open circuit and the second jumper should be moved closer to the first and another attempt made to lift the first jumper. No dynamic arc, however, indicates the fault to be beyond the second jumper.

b. If no lamps are lighted after the first short is made, the open is toward the regulator. Jumpers are removed and placed nearer the regulator and the whole procedure repeated.

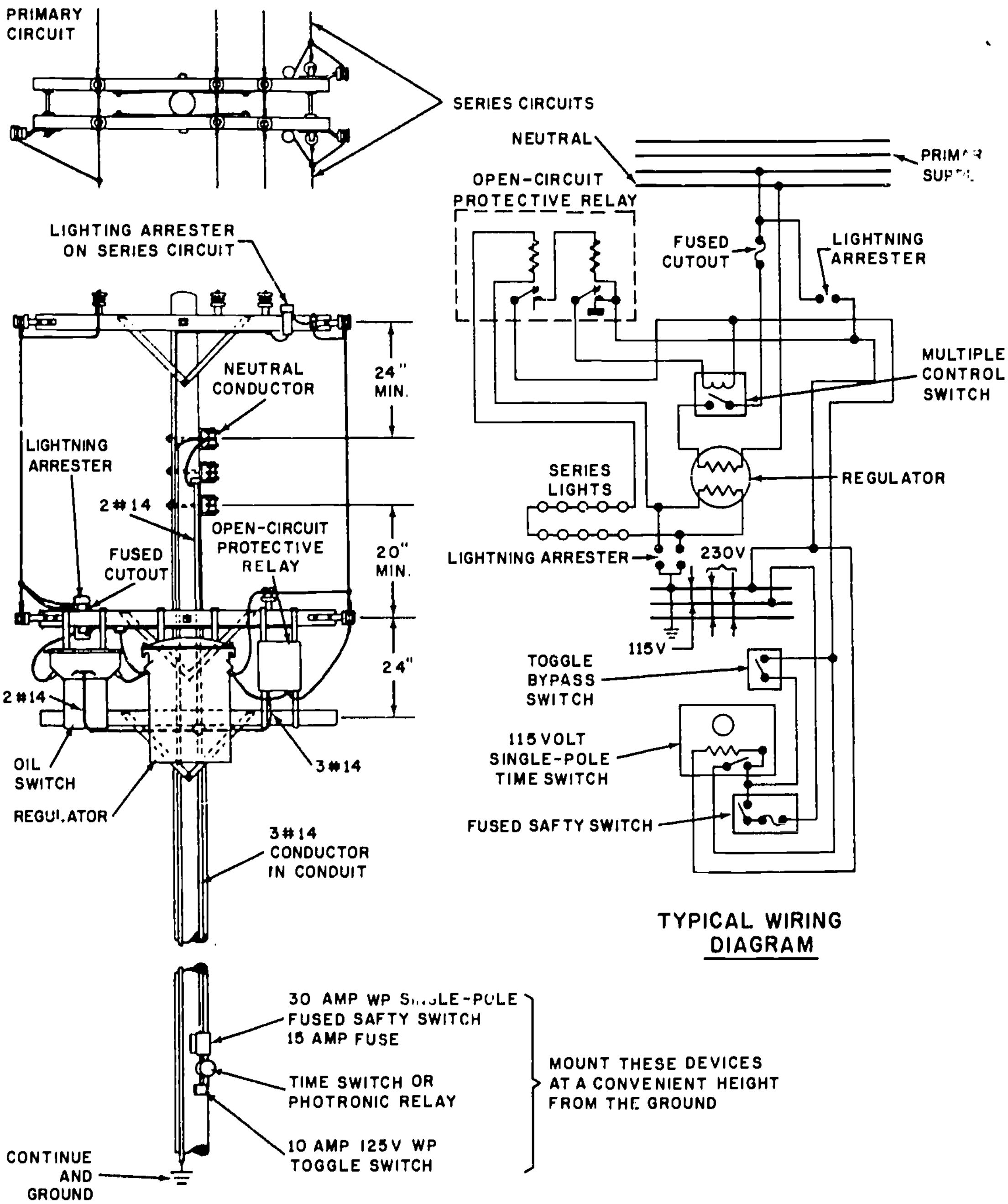
2. Open Loop. The open-loop series circuit is worked similarly to the closed loop except that, instead of shorting, the conductors may be temporarily grounded (using primary or secondary ground wire if present) at two points. This shorts out the portion of the circuit between the grounded points. The lamps in the shorted portion will not burn if it has the open, but the lamps in the remaining portion will light up.

USING A MEGGER

Faults may be located with the street circuit dead by using a 1,000-volt megger. The primary cutouts must be first opened and tagged. The megger is used in place of the jumper, with a high (infinity) reading indicating an open in the portion of the circuit being meggered. A jumper may be installed at each point meggered and after each meggering until the open has been located. All jumpers must be removed after the fault has been located and repaired.

OBSTRUCTION LIGHTING

Obstruction lights are used to indicate the existence of obstructions. These lights are red in color, with an intensity of not less than 10 candlepower. The number and arrangement of



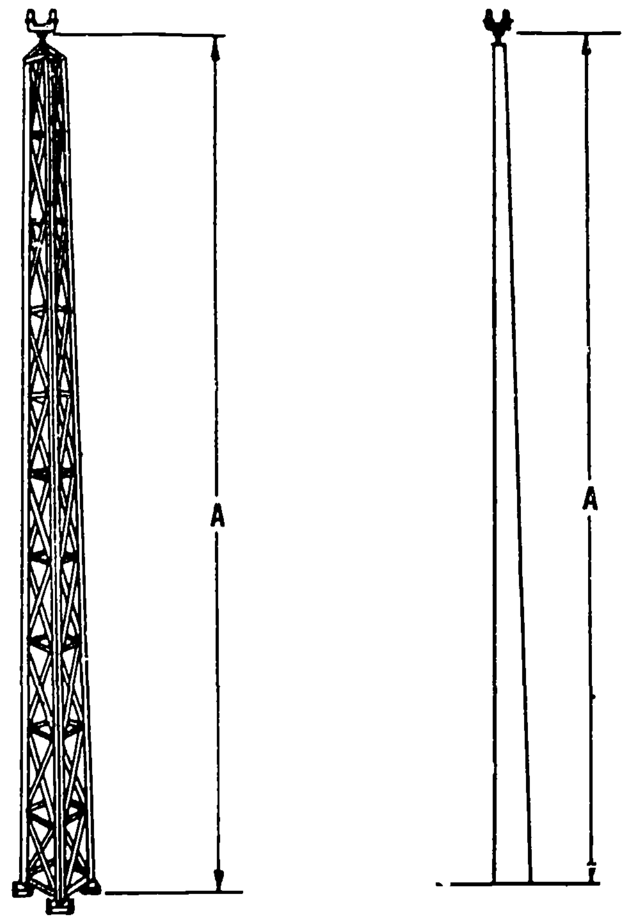
73.365

Figure 10-68.—Schematic diagram of pole-mounted installation.

Table 10-3.—Troubleshooter's Guide, Series Circuit

TROUBLE	POSSIBLE CAUSE
LAMPS FAIL TO BURN, EVEN DIMLY.	(1) PRIMARY FEEDING CONDUCTORS OPEN. (2) PRIMARY FUSES BLOWN. (3) PRIMARY FUSE CUTOUTS DROPPED OUT. (4) PRIMARY OIL SWITCH OPEN. (5) SERIES OR MULTIPLE CONTROL CIRCUIT OPEN. (6) PRIMARY PROTECTIVE RELAY OPEN. (7) STREET CIRCUIT OPEN. (8) PRIMARY LEADS TO REGULATOR OPEN. (9) DEFECTIVE REGULATOR.
LAMPS BURN DIMLY.	(1) REGULATOR OVERLOADED. (2) SECONDARY CONNECTION POOR. (3) POOR CABLE INSULATION CAUSING LEAKAGE TO GROUND. (4) REGULATOR MOVING MECHANISM OUT OF ORDER.
EXCESSIVE BURNOUTS.	(1) HIGH AMPERAGE (CABLE HOLDING SECONDARY MAY BE BROKEN). (2) LIGHTNING. (3) POOR LAMPS.
LAMPS BURN NORMALLY, EXCEPT FOR ONE OR TWO WHICH BURN DIMLY.	(1) FILM CUTOUT PARTIALLY FAILED. (2) VOLTAGE LEAKING TO GROUND. (3) BREAKDOWN IN INSULATING TRANSFORMER. (4) INCORRECT LAMP SIZE. (5) LAMPS ABOUT TO BURN OUT.
FILM CUTOUT FAILS BUT LAMP NOT BURNED OUT.	(1) IMPROPER CUTOUT USED. (2) ABNORMAL LINE SURGES. (3) LAMP LOOSE IN SOCKET.
WATER IN FIXTURE.	(1) BRACKET THREADS IMPROPERLY REDLEADED. (2) JOINTS IMPROPERLY GASKETED.
ABNORMAL BREAKAGE OF GLASSWARE.	(1) FIXTURE OVERLAMPED. (2) HOLDER ACCOMMODATES GLASSWARE IMPROPERLY. (3) WRONG GLASSWARE FOR FIXTURE. (4) ABNORMAL EXTERNAL VIBRATION. (5) EXTERNAL DAMAGE BEYOND CONTROL.
SOCKETS AND RECEPTACLES BURNED AND PITTED.	(1) CONNECTIONS LOOSE. (2) CUTOUT NOT BREAKING DOWN COMPLETELY. (3) VOLTAGE LEAKING ACROSS SOCKET. (4) SOCKET FITTING RECEPTACLE IMPROPERLY. (5) LAMP NOT MAKING CONTACT IN SOCKET.
ABNORMAL DETERIORATION OF METAL PARTS.	ATMOSPHERE CONTAINS GASES OR VAPORS ATTACKING METALS.

73.366



A = NOT MORE THAN 150 FT.
NOTE:
WHERE "A" EXCEEDS 150 FT. INTERMEDIATE LIGHTS WILL BE REQUIRED FOR EACH ADDITIONAL 150 FT. OR FRACTION THEREOF.

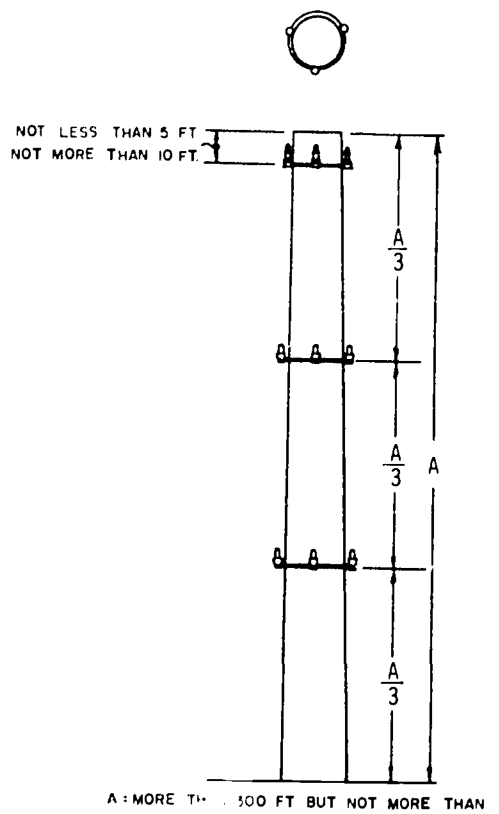
73.323

Figure 10-69.—Lighting of towers, poles and similar obstructions.

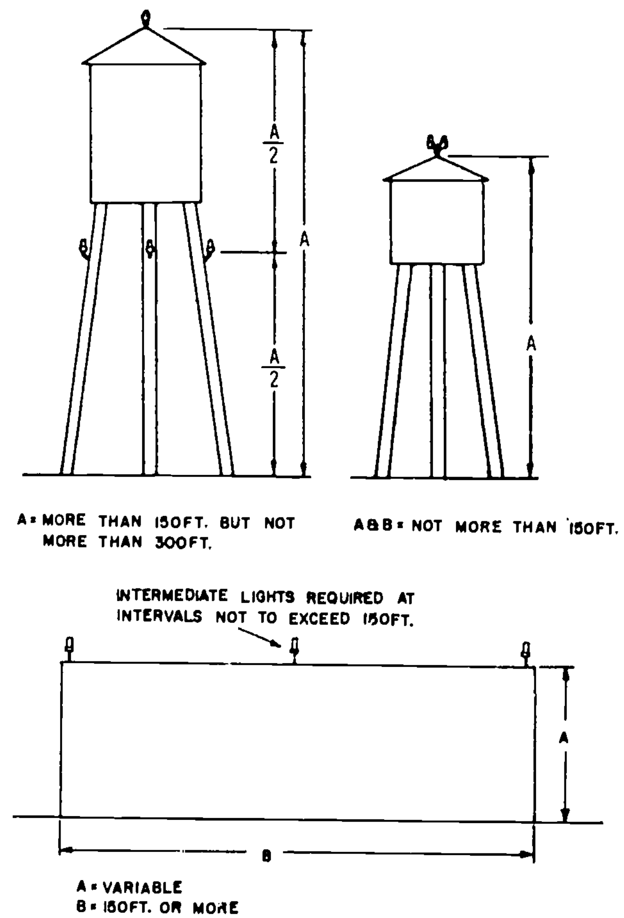
lights at each level to be lighted should be such that the obstruction is indicated from every angle of azimuth. Figures 10-69 through 10-71 illustrate these methods of lighting.

VERTICAL ARRANGEMENT

At least two lamps, either operating simultaneously or circuited so that upon failure of



73.324
Figure 10-70.—Lighting of smokestacks and similar obstructions.



73.325
Figure 10-71.—Lighting of water towers and similar obstructions.

one, another becomes operative, will be located at the top of the obstruction. An exception is made in the case of a chimney or similar structure, on which the top lights are to be placed between 5 and 10 feet below the top. Where the top of the obstruction is more than 150 feet above the level of the surrounding ground, an intermediate light or lights will be provided for each additional 150 feet, or fraction thereof. These intermediate lights will be spaced as equally as practicable between the top light, or lights, and the ground level.

HORIZONTAL ARRANGEMENT

Obstructions consisting of built-up and tree-covered areas are examples of extensive obstructions. Where an extensive obstruction or a group of closely spaced obstructions is marked with obstruction lights, the top lights will be displayed on the point or edge of the obstruction highest in relation to the obstruction marking surface, at intervals of not more than 150 feet. If two or more edges of an obstruction located near an airfield are at the same height, the edge nearest the airfield will be lighted.

LIGHTING OF OVERHEAD WIRES

When obstruction lighting of overhead wires is needed, the lights will be placed not more than 150 feet apart at a level not below that of the highest wire at each point lighted. When the overhead wires are located more than 150,000 feet from the center of the landing area, the distance between lights may be increased to no more than 600 feet.

CHAPTER 11

UNDERGROUND POWER DISTRIBUTION

Underground power distribution and communication systems are used by the U. S. Armed Forces for the following reasons:

1. Underground lines are secure against damage inflicted by high winds and storms on overhead lines in some areas.
2. Overhead lines often interfere with clear approach to aircraft landing fields.
3. Underground lines leave clear areas and open spaces for the operation of cranes and other mobile equipment.
4. Underground lines are m ch more secure against enemy attack than overhead lines.

This chapter presents information on installation and maintenance procedures applicable to underground power distribution systems. The structure and function of manholes and handholes, and the steps involved in pulling cable are described. Of particular interest to you is the section containing detailed cable splicing instructions. Safety precautions that you must observe are outlined, and a general overview of airfield lighting systems is given.

CONSTRUCTION

There are three principal categories of underground lines: duct lines, cables buried directly, and conduits located in tunnels. The system most frequently installed by construction battalions is the underground duct system, with its attendant manholes, ha dholes, duct lines, and cables.

MANHOLES AND HANDHOLES

Manholes and handholes (a handhole is essentially a small manhole) are installed at intervals along an underground line to facilitate the installation, removal, splicing, and rearrangement of the underground conductors. The conduits enter the vault of a manhole along the side walls, and devices attached to the walls support the cables inside the manhole.

Manholes are installed not more than 500 ft apart because the mechanical strain placed on the sheath and conductors of a cable may become too great during the pulling-in process. The best shape for the vault of a manhole is usually elliptical or oval to prevent the necessity for sharp bends in the cables passing through the manhole. Care should be exercised not to exceed the manufacturer's recommended bending radius for individual cables when installing or pulling them in manholes and handholes.

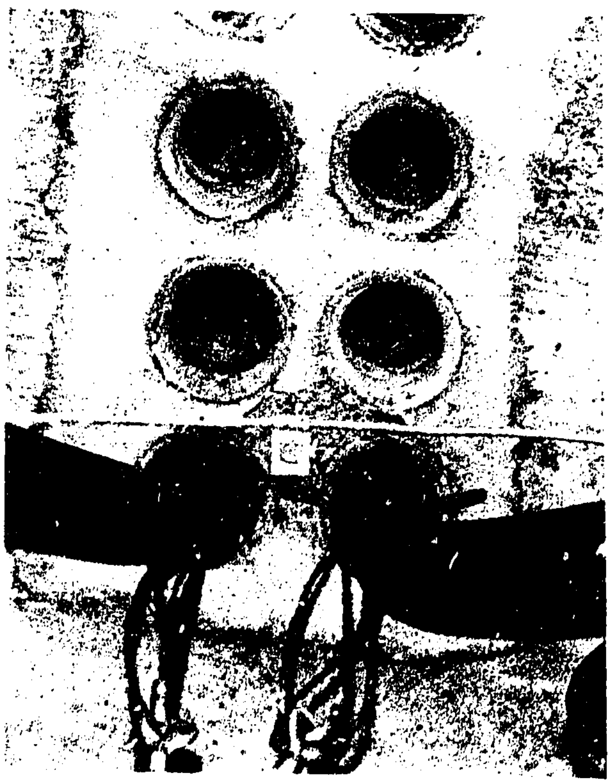
A manhole should have at least 6 ft of headroom, so that men working on cable will not have to assume stooped positions. Average inside horizontal dimensions are 5 ft by 7 ft, though a manhole may be smaller if it contains only a few duct openings. Duct openings a manhole wall are shown in figure 11-1.

If possible, a drain to a sewer line should be installed in the bottom of a manhole. If this is not possible, there should be at least a drain hole in the floor to allow water to drain out. A cavity below the floor, off to the side, and filled with broken rock as shown in figure 11-2, will facilitate the draining process.

A handhole is used principally as a pull or junction space. It serves the same purpose as a pull box in interior wiring. A handhole is usually about 4 ft square and from 24 to 36 in. deep, with a metal cover the full size of the hole.

DUCTS AND TRENCHES

Several types of underground ducts are in general use, such as fiber, wood, vitrified tile, iron pipe, asbestos composition, and concrete. The type generally used by the Navy is a fiber type with the trade name "Orangeburg." This is a conduit which is made of wood pulp treated and thoroughly saturated with a bituminous compound. The compou contains about 6 percent



73.105
Figure 11-1.—Duct openings in a manhole wall.

creosote to prevent rotting in the ground. Sections are joined to each other with a self-aligning coupling, and can be laid in a trench very rapidly. The duct has a smooth, oily surface which allows cables to be drawn through easily. It comes in 8-ft lengths, and can be easily cut to any desired length with an ordinary wood crosscut saw.

A standard 8-ft length of fiber cut is made with a turned-down space at each end to accommodate the coupling. When you cut a length, you have to make this turn down at the cutoff end. The tool used for this purpose is called a "field tooling lathe." Figure 11-3 shows the lathe dismantled. Figure 11-4 shows the lathe on a piece of duct after making the cut. The lathe is set to cut the exact amount from the piece of duct to ensure a tight fit between the coupling and the duct. In some locations you may not have this tool available, and will have to use a coarse file or rasp. Be careful not to cut too deeply.

An underground installation will usually consist of several duct lines. Joints between sections should be staggered, so that the joints in several lines will not all occur at the same place. To ensure staggering, starting sections of different lengths are used at the starting manhole. For duct set in concrete, there must be at least 3 in. of concrete around each line of duct. This spacing is ensured by the use of spacers like the one shown in figure 11-5. The upper lines of duct must be at least 2 ft below the ground surface.

The location of the trench will vary according to ground conditions, but it should run as nearly as possible in a straight line from one manhole to the next. To ensure drainage, the line should slope downward about 1 ft but never less than 3 inches every 100 horizontal ft. If one manhole cannot be located at a lower level than the other, the line must slope downward from about the midpoint both ways toward the manholes.

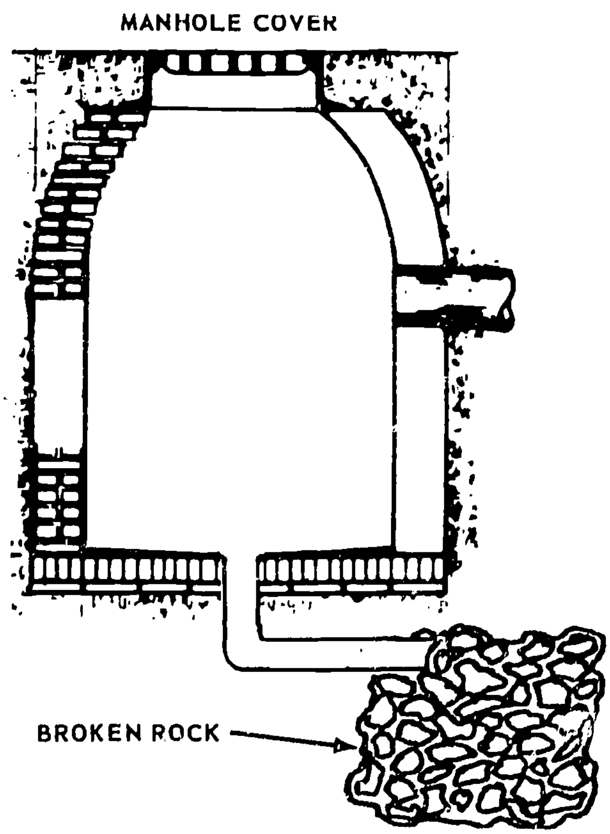


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Figure 11-2.—Drain pit for manhole.

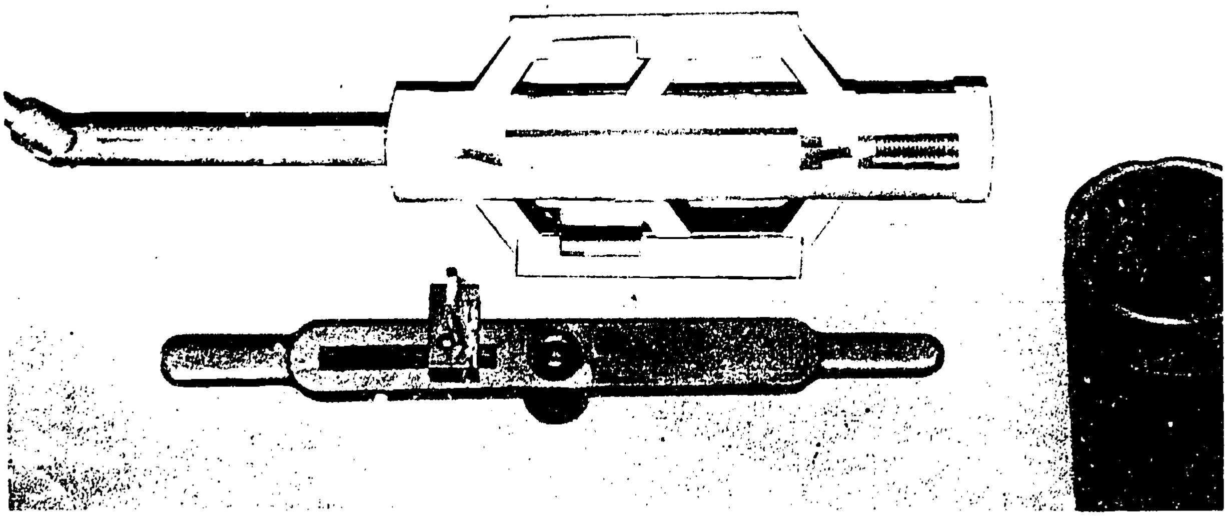

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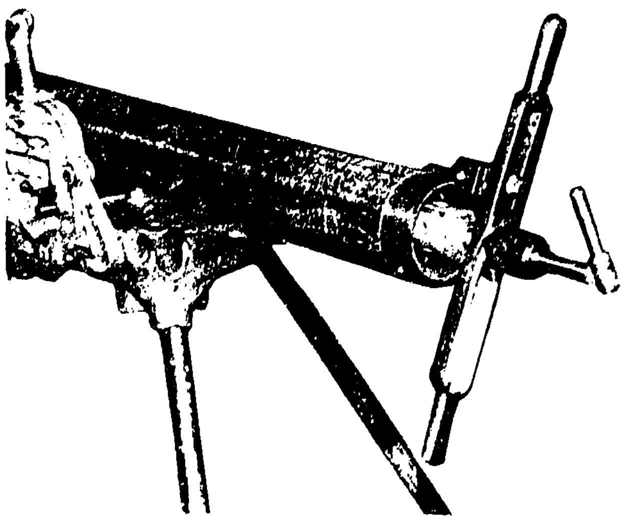
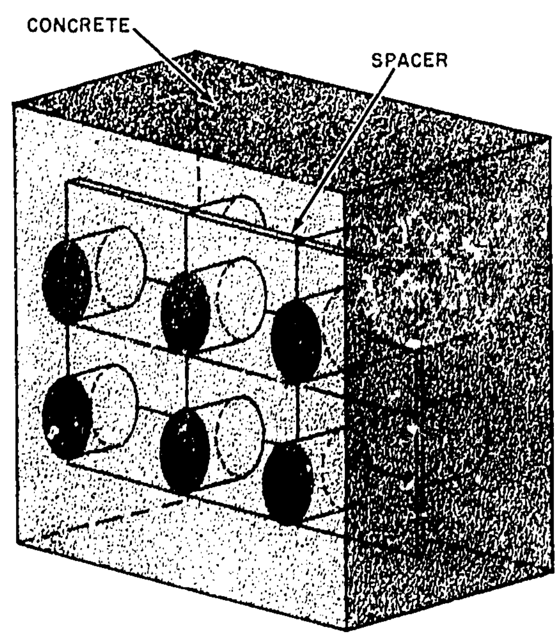
Figure 11-3. — Field tooling lathe dismantled.



73.109

Figure 11-4. — Field tooling lathe set for turning down fiber duct.



73.107

Figure 11-5. — Spacing fiber duct in concrete.

Dig the trench to the desired depth and tamp the bottom hard to ensure a solid bed for the 3-in. bottom layer of concrete. Spacers can be embedded in the bottom layer of concrete for a depth of about 1 in. before the concrete sets to ensure a solid base.

UNDERGROUND CABLE

Underground cables have various types of insulation and sheaths. Because higher voltages generate more heat, the amount of voltage carried determines the composition of the insulation.

Cables rated at 5 kv and below usually have rubber of varnished cambric insulation and a lead or rubber sheath. Those rated at 600 volts to 425 kv have oil-impregnated paper insulation and a lead sheath.

Cables rated at 5 kv and above have metallic tape shields between the insulation and sheath for mechanical protection. Exceptions to this are single conductor (1/c) cable with a lead sheath and three conductor (3/c) belted type cable.

Much of the new cable being installed is cross-linked-polyethylene (XLP) or ethylene-propylene-rubber (EPR). These are called solid type insulations. The size and number of conductors in the cable will depend on the job requirements.

PULLING CABLE

When you install a new run of duct you pull in "pulling wire," usually a 10-gage iron wire. With this wire you pull in a wire rope, to which you attach the lead-covered cable for pulling in.

Sometimes, if the duct has been in the ground a long time, the original iron pulling wire may be rusted so that it is not strong enough to pull the wire rope through. For a 400- to 500-ft run you would also have difficulty pushing a fishtape through the duct. The job can be simplified by using an air compressor to blow a chalk-line cord through the duct. To do this, take a small cloth, and tie the chalk line end to the four corners, so the cloth will function like a small parachute. With the airhose in the end of the duct and the cord free to run out, you will be able to blow the cloth through to the next opening, even on a long run of duct.

Cleaning ducts is accomplished by rodding. Quick-coupling duct rods (about 4 ft long and 1 in. diameter) are connected together with a wire brush or other duct rod leader at the head to facilitate cleaning. The rods may be pushed through manually or by means of power equipment. A 12-gauge galvanized steel wire attached to the leader is left in the duct for the cable pulling crew.

Only a very little moisture under the lead sheath is enough to cause a breakdown of the insulation between the conductors or between the conductors and the ground. For this reason, when pulling in cable, you must be very careful with short bends or any other conditions that might cause cracks or damage in the lead sheathing.

Figure 11-6 shows a way of preparing cable for pulling in a duct line. This procedure ensures that the cable will not pick up any moisture while being pulled through the duct.

Step 1: Cut back the lead sheath with four V-shaped cuts.

Step 2: Bend the lead sheath back over the cable and remove all insulation and metal tape.

Step 3: For a three-conductor cable, separate the strands of all three conductors and bend back over the sheath.

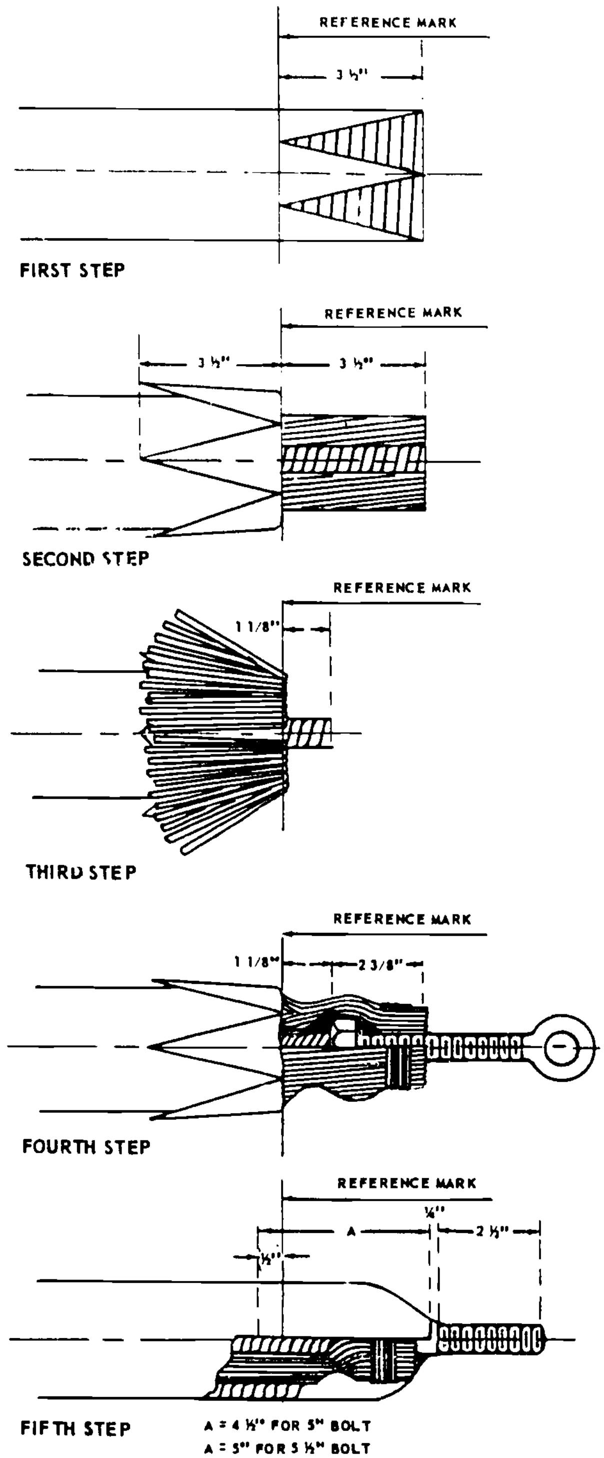
For a single-conductor cable, bend the two outer layers of strands back over the sheath, and cut the remaining strands 1 1/8 in. from the reference mark.

Step 4: Place the head of the bolt as shown. Then bend the outer strands over the assembly to fit evenly on the shank of the bolt. Bind the strands with six turns of No. 14 copper wire and sweat thoroughly.

Note: If the strands of the outside layer do not fit evenly around the shank of the bolt, remove from the outer layer three strands equally spaced from each other before making the sweat.

Step 5: Beat the ends of the sheath forward over the solder sweat. From a point 1/2 in. beyond the reference mark, make a waterproof wipe over the sweat. The outside diameter of the wipe must not exceed the outside diameter of the cable.

Tin the head and the unthreaded portion of the bolt thoroughly before installing in the end of the cable. The threads of the bolt must be clean of solder and well greased to ensure easy running of the nut. Do not use bolts on which the threads are in uncatisfactory condition. Use great care to make the wipe waterproof.



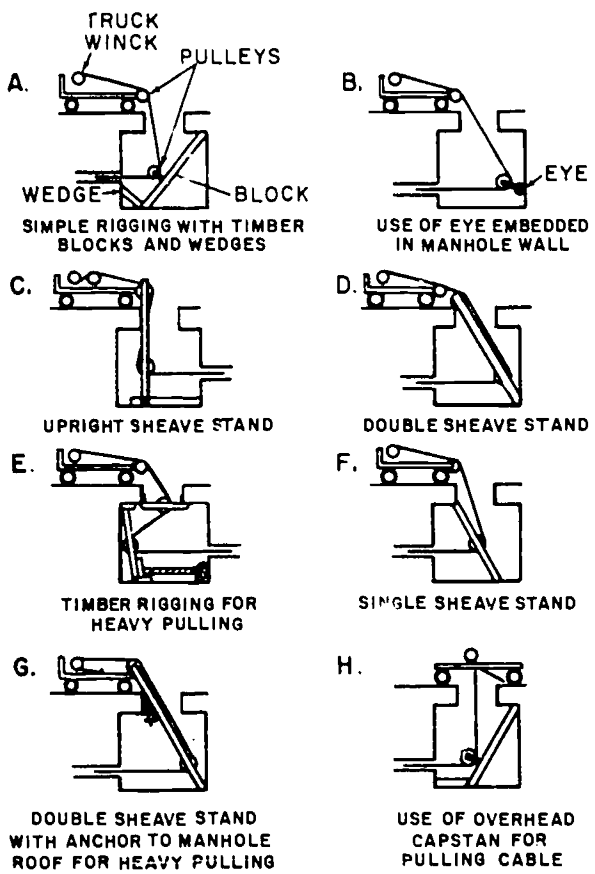
73.110

Figure 11-6.—Installing pulling bolt on lead-covered cable.

RIGGING

Figure 11-7 illustrates a number of ways to rig manholes for cable pulling. View A shows the cable pulley attached to a timber block which, in turn, is supported by a wedge. In view B, the pulley is shown attached to the manhole wall by means of an embedded eye. If you use this method, make sure that the lower sheave is in line and level with the duct in which the cable is to be pulled. To prevent injury to the cable by sharp edges, line the duct mouth with a shield.

Either of the above methods will probably be satisfactory for most of the jobs you will handle. Sometimes, however, more complex rigging is called for, especially in cases when the cable requires heavy pulling. For jobs of this nature, you will find the other views in figure 11-7 helpful.



73.370

Figure 11-7.—Manhole rigging for pulling cable.

When pulling lead-covered cables into a long duct, use a feeding tube or bell for applying a lubricant at the duct mouth. Make sure you use the lubricant specified by the manufacturer of the cable.

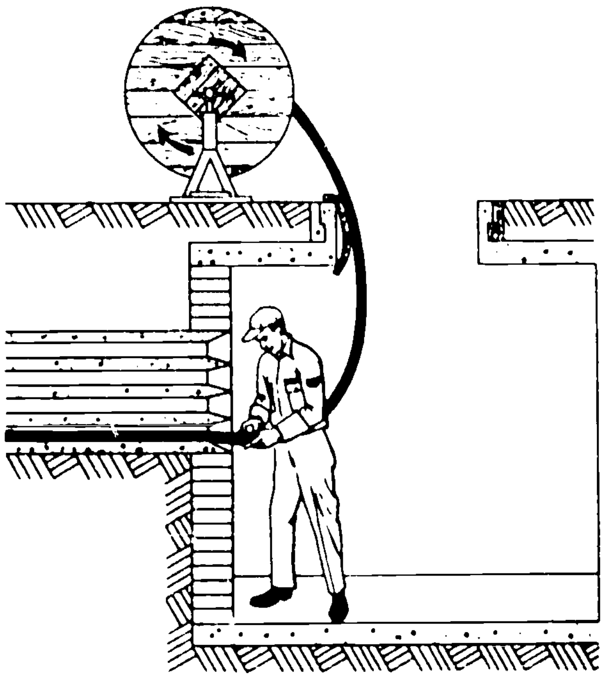
REEL PLACEMENT

Make a plank runway to support the reel for movement over areas where dirt, cinders or crushed stone might damage the cable. All cable reels are marked with an arrow indicating the direction in which they must be rolled. Comply with this arrow when placing the reel at a manhole so that it turns in the proper direction as cable is pulled from the reel. Place the reel as near as practicable to the manhole and raise it on reel jacks just enough to clear the ground. Figure 11-8 shows a reel in proper position over the manhole so that the bend in the cable is not reversed as the cable is unreeled. Notice the scuff boot at the edge of the manhole to prevent damage to the cable sheath. A section of an old tire casing can serve as a protective boot for this job.

The boards nailed to the two edges of the reel are called lagging. When the reel is in place, remove this lagging. You must be careful not to damage the cable when you pry the lagging loose. Be sure to remove any projecting nails from the edge of the reel before starting to remove cable. Next you must release the end of the cable from the reel, and you will then be ready for the main part of the job.

Assume that the winch line has been drawn into the duct as the test line was pulled out. A basket grip is now attached to the end of the underground cable on the reel. The end of the basket is secured to the cable with a tight wrap of tape or wire. A swivel connection is necessary between the basket and the pulling cable to relieve twisting of the rope.

If the cable reel is within sight of the winch, it will take four men, in addition to the winch operator, to do the job safely. One man attends the reel to see that the cable pays off the reel properly. Another man in the manhole guides the cable into the duct. Both men inspect the cable as it unreels and immediately signal "stop pulling" if a defect appears so that a



73.371
Figure 11-8. — Reel in proper position.

closer inspection can be made for possible damage to the sheath. A third man, stationed in the other manhole at the pulling end, signals "stop pulling" when the cable appears. The fourth man aboveground at the pulling-end manhole, relays signals to the winch operator. This procedure enables the winch operator to concentrate on his job of seeing that the winch line is wound into the reel properly.

The speed for pulling cable into a duct varies with the length of the duct and cable size. A single cable can be pulled in successfully at 75 feet per minute in a clear, straight duct. If you are handling more than one cable, reduce the speed to about 20 to 25 feet per minute so you can prevent the conductors from crossing as they enter the duct.

When the "stop pulling" signal is given, make sure there is sufficient slack in both manholes for splicing or terminating the cable. The slack can be adjusted with the cable basket grip. Exercise care to prevent injury to the cable insulation. Remove binding tape and basket grip from the cable. The cable is then cut to the desired length and the cutoff end in the manhole is sealed unless splicing is done immediately. The end of the cable remaining on the reel must also be sealed. In addition, check the seal on the end of the cable which has traveled through the duct, and reseal if it has broken from the strain.

SPLICING UNDERGROUND CABLE

A primary consideration in splicing underground cable is to keep moisture out of the splice. The first thing to do in the manhole, then, is to make it as dry as possible. If there is water on the floor, pump it out, because standing water can cause condensation to accumulate on your tools and on the cable.

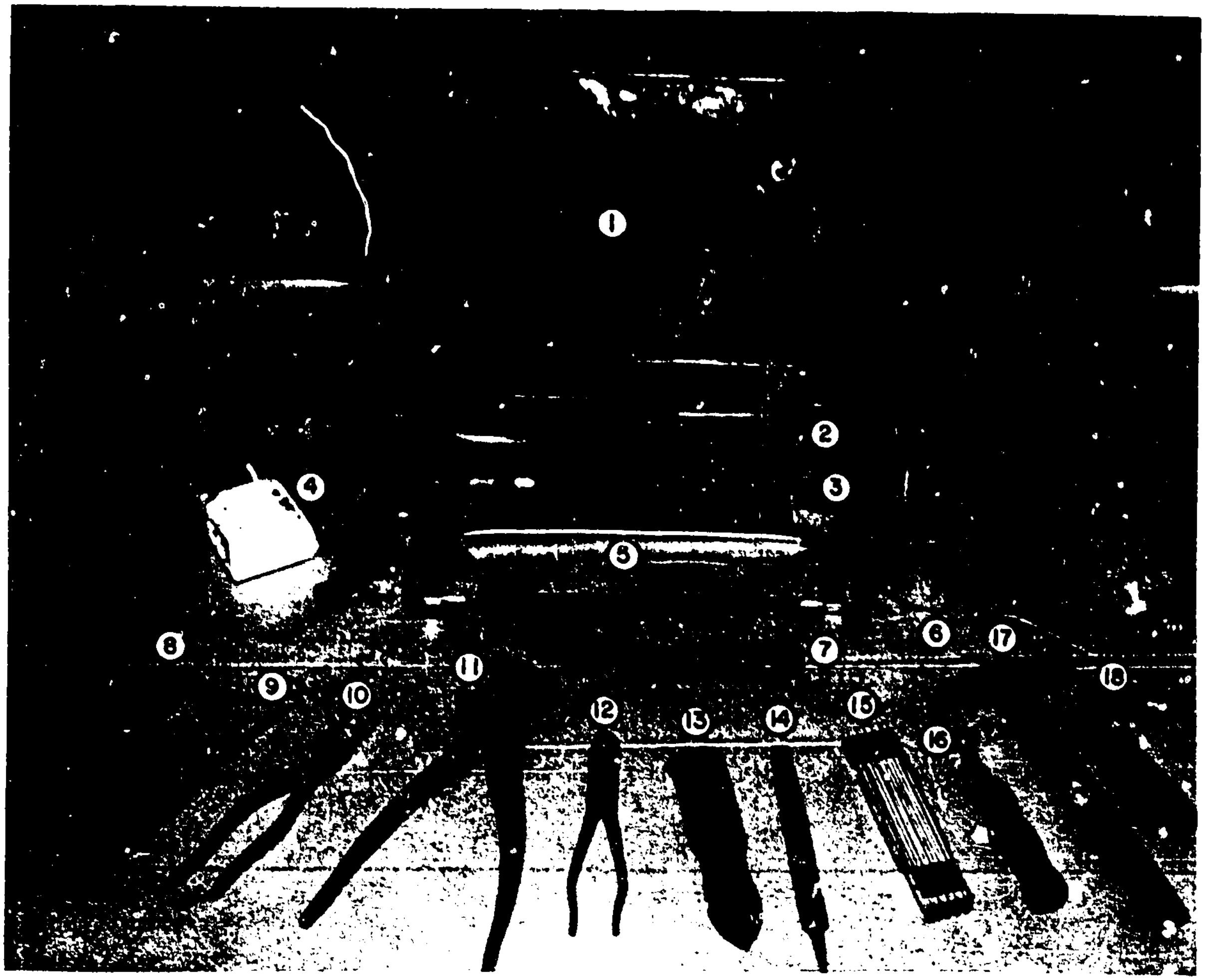
The splicing procedures outlined in the following sections apply to most types of cable. Variations in technique are dictated by differences in cable construction. Factors influencing changes are: the kind of insulation, presence or absence of a conducting shield, and whether the cable is single or multiple conductor.

PREPARING A LEAD SPLICE

The principal steps in cable splicing are (1) preparing the cable for splicing by removing the lead sheathing and insulation from the conductor and cleaning the conductor, (2) sweating the connector on the conductor and polishing the connector, (3) reinsulating the joint, installing the sleeve, and wiping the ends of the sleeve to the cable sheath, and (4) filling the sleeve with insulating compound. Each of these steps is essential, and a poor job on any one of them will result in a faulty splice. Figure 11-9 shows most of the tools used in splicing underground lead cable.

Assume that the cable shown in figure 11-10 is size 4/0, and that it is a straight joint, rubber-insulated, lead-covered cable rated at 5000 volts. The table in figure 11-10 shows that for splicing a size 4/0 cable you use a sleeve 2 1/2 in. in diameter and 11 in. long.

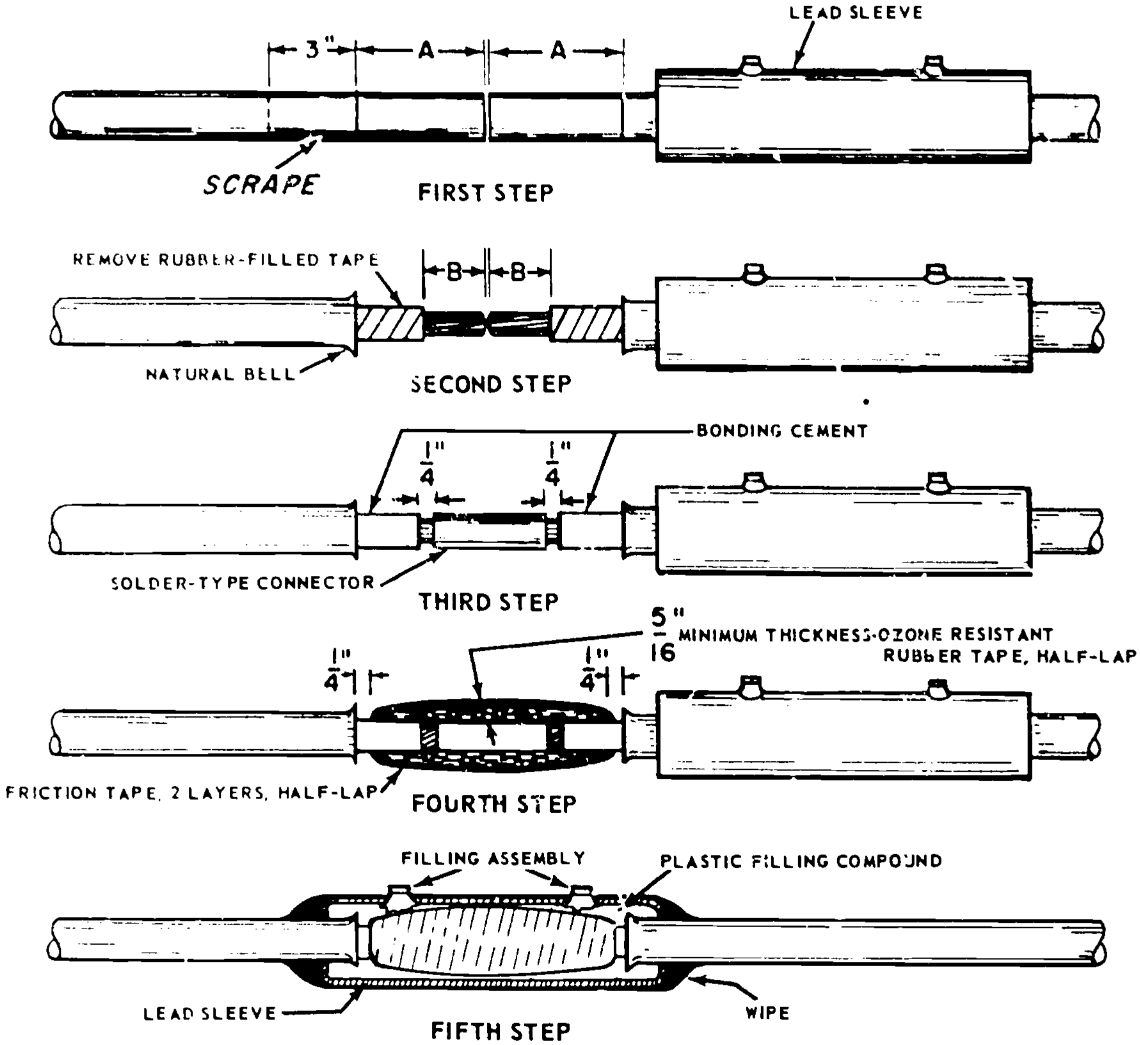
Scrape or rasp about 3 in. all around each end of the sleeve and coat with a compound called "stearing." Now use the triangular scraper, frequently referred to as a shave hook (fig. 11-9, number 18), to smooth the inside of the sleeve, so as to have a slight inside



1. Splash pan
2. Dressing tool
3. Soldering copper
4. Stearine block
5. Hack saw
6. Cotton tape
7. Cable sheath splitting knife
8. Diagonal pliers
9. 8" screw driver
10. Ringing tool
11. Parrot-nose pliers
12. Crimping tool
13. File card
14. Rasp
15. Wooden rule
16. Hook knife
17. Riveting hammer
18. Triangular scraper

73.111

Figure 11-9.—Tools and material for splicing lead cable.



TABLE

CODE NO	SIZE OF LARGER CONDUCTOR AWG OR MCM	DIMENSIONS (INCHES) LEAD SLEEVE I D	LEAD SLEEVE LENGTH	CONNECTOR LENGTH	A	B
1	6	1 ½	9	1 ½	3 ½	1
2	3	1 ½	9	2	3 ½	1 ¼
3	2	1 ½	9	2	3 ½	1 ¼
4	2/0	2 ½	11	2	4 ½	1 ¼
5	4/0	2 ½	11	2 ½	4 ½	1 ½
6	350	2 ½	11	2 ½	4 ½	1 ½
7	500	2 ½	12	3	4 ¾	1 ¾
8	750	3	13	3 ½	5	2
9	1500	3 ½	18	5	5 ¾	2 ¾
10	2000	3 ½	18	6	6 ¼	3 ¼

73.113

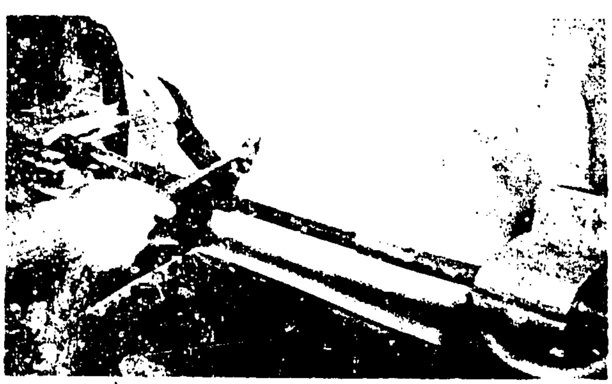
Figure 11-10. —Steps in lead cable splicing.

bevel at each end. Then slip the sleeve over one end of the cable and push it back out of your way as shown in the first step of figure 11-10.

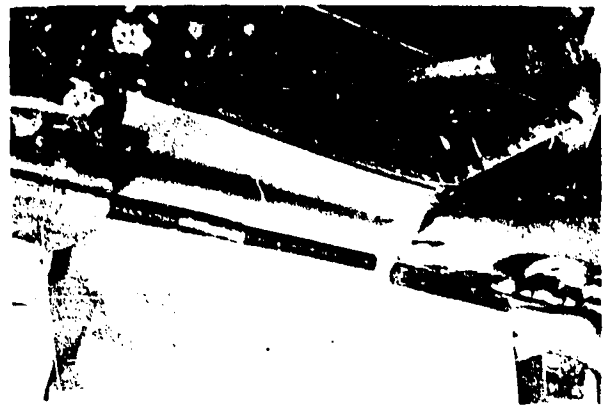
Referring again to the table in figure 11-10, you will see that the "A" dimension for a 4/0 cable is 4 1/2 in. Measure 4 1/2 in. from each end and mark this distance by a shallow ring (NOT a deep or through ring) around the sheath. Now take the triangular scraper and clean about 3 in. back from the "A" ring on each cable end. Coat the area (which is where the sleeve will join the sheath when the splice is finished) with stearine.

Split the sheath on each conductor end 4 1/2 in. back, using the cable sheath splitting knife (fig. 11-9, number 7) and a ball-peen hammer (fig. 11-11). Hold the knife at an angle so you don't cut the insulation on the conductors, and each time you hit the knife give it a slight twist. This tends to turn up one side of the split, and helps to ensure that you do not cut or scrape the conductors.

When you have split up to the cut ring on the sheath, start pulling the sheath away from the conductors until it breaks at the ring (fig. 1-12). If you do not cut too deep a ring, a natural bell will form at the remaining end of the sheath, as shown in the second step, figure 11-10. The bell prevents any rough edge from cutting the insulation, and also allows compound to flow under the sheath and give better protection. First take a roll of cotton tape and make three wraps around the exposed insulation from 1 1/2 in.



73.114
Figure 11-11. - Splitting sheath with cable sheath splitting knife.



73.115
Figure 11-12. - Removing sheath from cable.

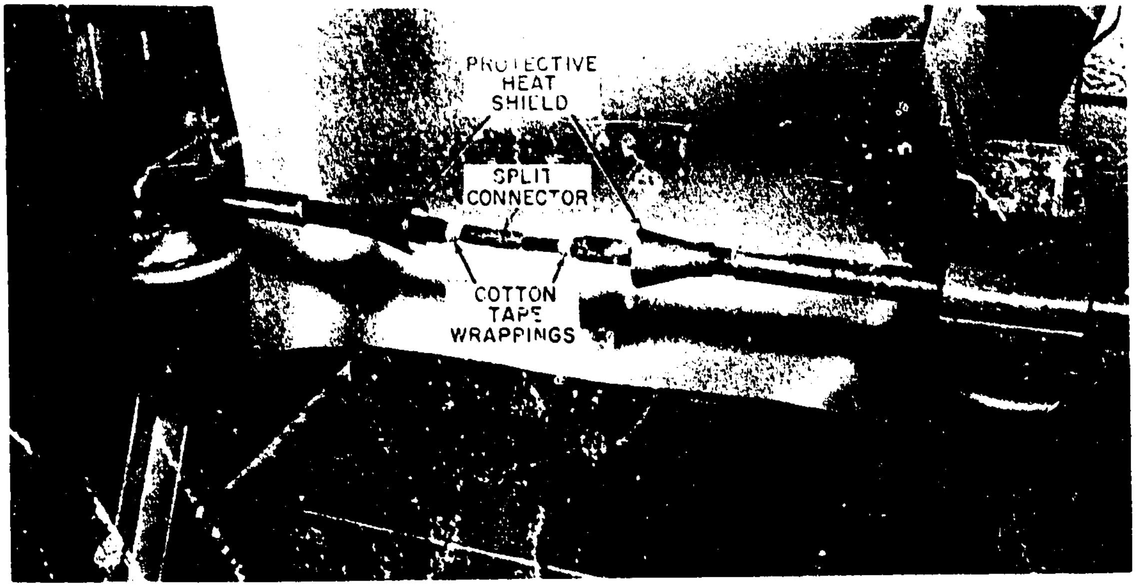
back from the end of the conductor to the sheath. Put the protective heat shields on the conductors by sliding them over the insulation (fig. 11-13). Then remove the belt insulation back to the cotton.

Splicing Conductors

Before you make the splice, you should refer to a bill of material like the one shown in figure 11-14. The table shown in figure 11-10 indicates that for a size 4/0 cable you use code 5. In figure 11-14, then, it is the column under code 5 (fourth column from the right) that contains material quantities for the splice in a 4/0 cable.

You are now ready to remove the rubber insulation on the ends of the conductors where the connector will be sweated on. For a 4/0 cable, this means 1 1/2 in. from each end (distance "B" in fig. 11-10). Cut 1 1/2 in. of rubber from each of the ends, remove the cut off insulation and pencil the insulation on each conductor end by tapering. Clean the exposed copper conductor very thoroughly with a small strip of emery cloth.

Now slip the connector onto the cable ends. This connector is a split copper sleeve, well tinned inside and outside. Figure 11-15 shows the connector and the materials used to splice it to the conductors. You may have to form the cable ends to get the connector over them, but do not spread the connector. When you have it centered on the ends, there should be a space



73.118

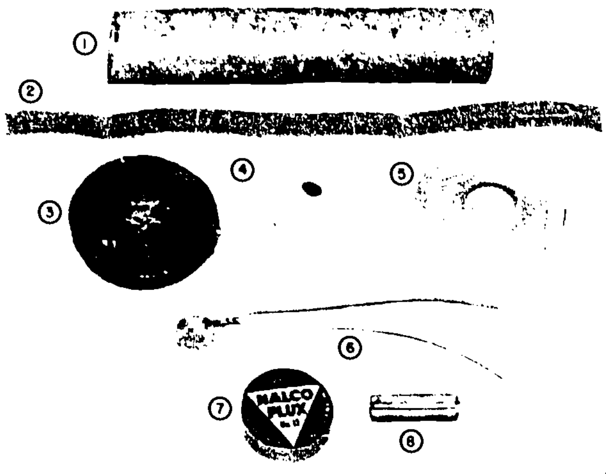
Figure 11-13.—Install'ng connector on conductor.

BILL OF MATERIALS FOR STRAIGHT JOINT
OF [illegible] CABLE

ITEM	UNIT	QUANTITY ([illegible])				
Code No.		1,2,3	4,5,6	7	8	9 & 10
Size of Larger Conductor (AWG or MCM)		6,3,2	2/[illegible],4/0,350	5[illegible]	750	1500 & 2[illegible]
Cloth, Abrasive #150 1-1/2" Wide	feet	6	6	6	12	[illegible]
[illegible]	[illegible]	5	5	5	6	12
Connector, Straight or Reducing	each	[illegible]	3	3	3	3
Cord, [illegible]	[illegible]	15	15	15	15	15
Flux, Stearine	[illegible] stick	1	1	1	1	1
Garters, Paper 2 1/2" x 12" Strips	each	9	12	12	18	24
Sleeve, [illegible] Plastic ([illegible] x Length)	each	3(1 1/2x9)	3(2 1/2x11)	3(2 1/2x12)	3(3x13)	2(3 1/2x18)
Solder, [illegible] (40-60) [illegible]	pound	4	6	6	9	12
Tape, Friction	roll	1	1	1	1	2
Tape, Ozone Resistant Rubber 3/4" Wide	roll	2	3	4	6	12
Wiping Rags	pound	1	1	1	1	1

65.10

Figure 11-14.—Bill of materia's for lead cable splicing.



1. Lead sleeve
2. Bonding tape
3. Friction tape
4. Cotton tape
5. Tape, ozone resistant rubber
6. Splice tag
7. Flux
8. Split connector

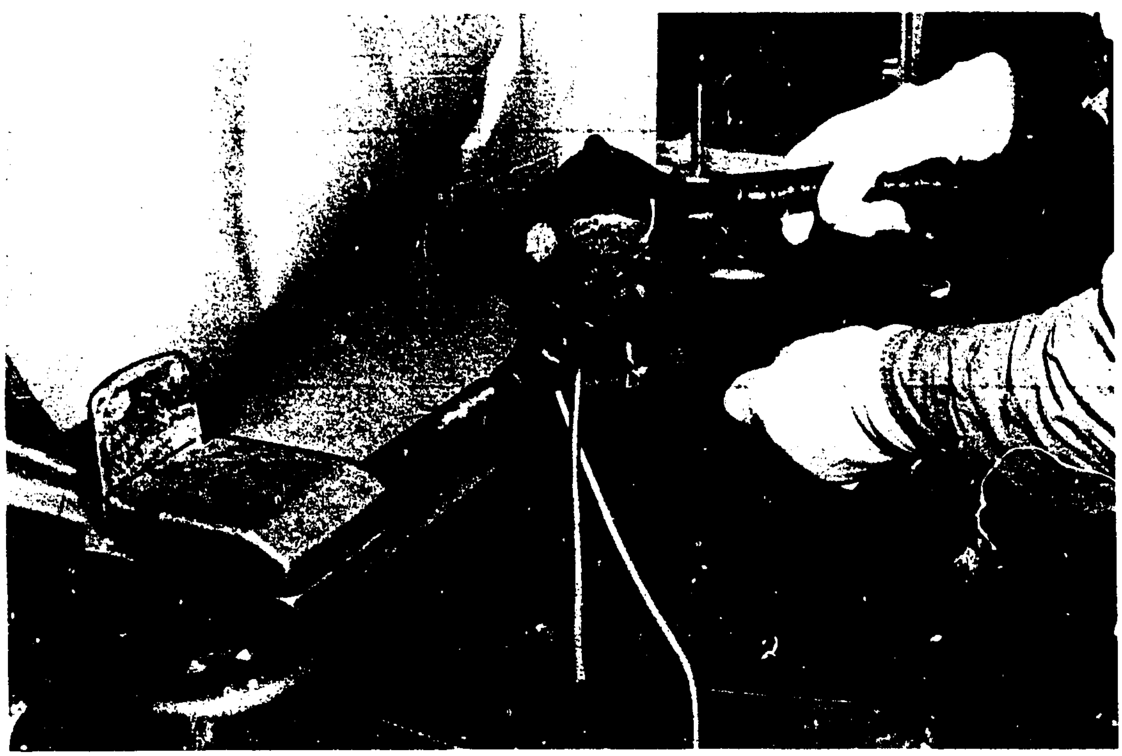
73.117

Figure 11-15.—Material for splicing conductor.

of about 1/4 in. between the end of the connector and the conductor insulation, as shown in the third step, figure 11-10. Fill this space with wrappings of cotton tape, as shown in figure 11-13, to protect the rubber insulation against the heat of the solder.

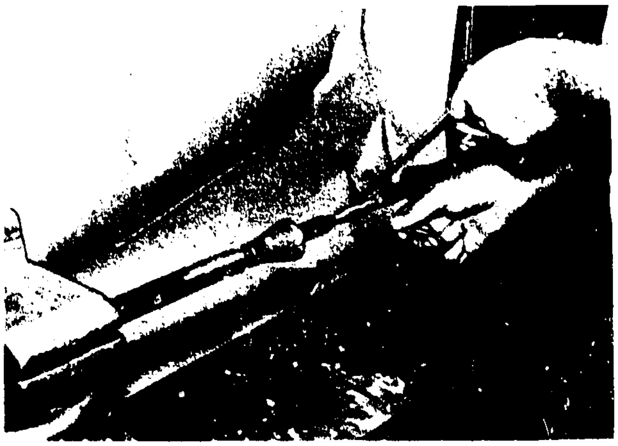
Be sure the connector is tight on the conductor ends, because there should not be any more solder inside it than is required to bond connector to conductor. Never use solder to fill space inside the connector. If a space exists, fill it with strands of copper wire. If the connector is still loose, use the crimping tool in figure 11-9 (number 12), to crimp the connector tight.

Now with two ladles (one to pour hot solder, the other to catch the drip, as shown in fig. 11-16) start pouring hot solder over the connector. Keep pouring until the connector is well heated and the solder completely penetrates the conductor and flows freely off the connector. Then make one last pour of mushy solder over the splice and lay the ladles down. Use a folded soft cloth and make a wipe from bottom to top on the back and then the front, leaving



73.119

Figure 11-16.—Soldering connector.



73.120
Figure 11-17. — Polishing connector.

a small ridge of solder over the split in the connector.

Clean the 1/4-in. space at each end of the connector, and then polish the connector using an emery cloth (fig. 11-17). The surface must have a very smooth finish, because any points or rough spots will cause a corona, which will in turn cause heating.

The connector is now sweated on, cleaned and polished. The next step is to wash away any traces of metal filings. To do this, use taping oil heated to approximately 230° F, using a portable furnace and melting pot such as those illustrated in figure 11-18 (numbers 4 and 5). Pour the hot oil over the connector, and over any bare metal which might have any metal filings or abrasive material on it.

Now take a pair of calipers and measure the diameter of the connector. The fourth step in figure 11-10 shows that there should be a MINIMUM of 5/16 in. rubber insulation on the connector. You therefore increase the connector diameter set on the calipers by twice 5/16., or 10/16 in., or 5/8 in.

You have 3 in. of rubber remaining between the sheath and the connector. This you coat with rubber bonding cement. Now start with ozone-resistant rubber tape at one end of the connector and fill the 1/4-in. space; then tape half-lap across the connector and fill the opposite 1/4-in. space. Continue back and forth, stopping each time 1/4 in. farther away from the lead sheath, until you have put on enough layers to bring the diameter of connector plus tape to that set on the calipers. Now put two layers of half-lap friction tape over the joint. The splice has now reached the stage shown in the fourth step, figure 11-10.

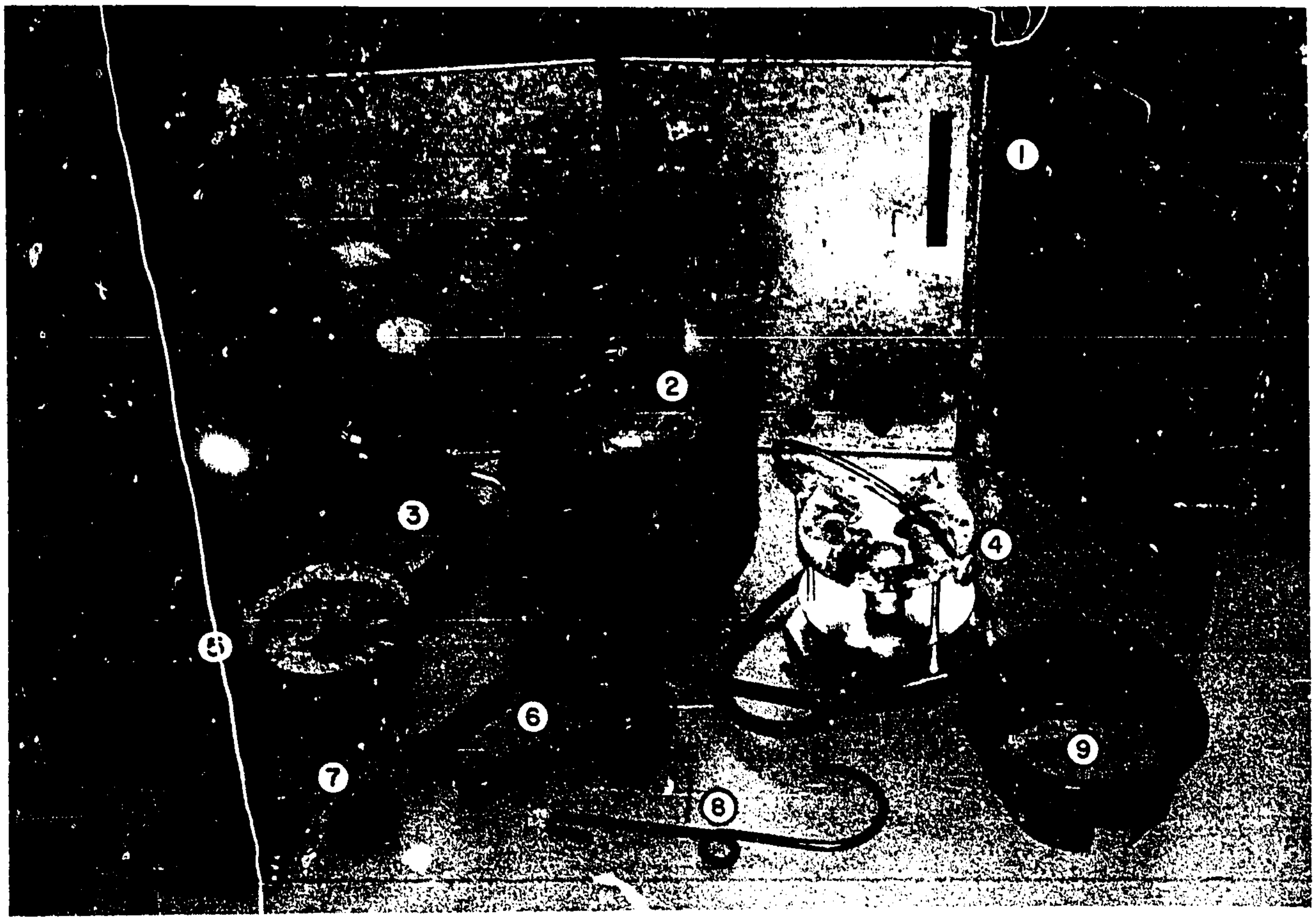
Wiping the Joint

The splice has been completed, and the next step is to wipe the sleeve to the cable and seal the joint. Most of the tools used for this are shown in figure 11-18.

Center the sleeve over the splice, and start forming the ends by rotating the sleeve and tapping lightly with a wooden dressing tool (fig. 11-19). If the bell starts getting too long, tap it lightly on the end. If it is too short, hit a few taps further back on the sleeve. Figure 11-20 shows a well-formed bell. After a little practice you will be able to control the shape quite easily.

Now you are ready to put the "pasters" on the sleeve and sheath. These are strips of gummed paper, 2 inches wide, that protect the lead sleeve and sheath from the initial heat of the wiping lead and give a smooth line to the finished wipe. On each end of the sleeve, about 1/4 in. back from the beginning of the bell, put a paster around the sleeve. Now about 1 in. from the bell of the sleeve put a paster on the cable sheath. Figure 11-21 shows pasters in place. The pasters outline the working space for the wiped joint. Take a small amount of hot lead and bond the sleeve to the sheath at one end. This bonding will prevent the sleeve from moving while you are wiping the joint at the other end.

Wiping is done in four stages: tinning, heating, rough-forming, and finish wiping. The tinning process is more or less the beginning of the heating process. Heat the wiping lead to approximately 760° F. If you do not have a thermometer, use a piece of folded brown paster paper to check for temperature as follows: Dip the paper in the lead and remove immediately. If it is scorched to the point where it appears about to ignite, the lead is hot enough to use. A 60/40 percent mixture of bar solder (60 percent lead and 40 percent tin) is the best mixture for wiping.



1. Wind shield
2. L-P tank and regulator
3. Hose and torch
4. Furnace
5. Melting pot
6. Ladles
7. Pads
8. Pot hook
9. Furnace hood

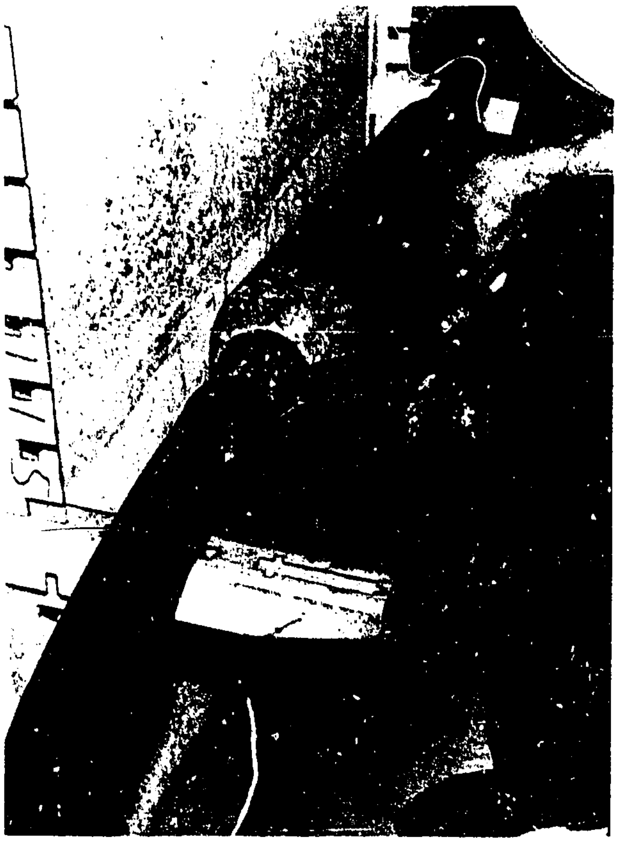
73.121

Figure 11-18.—Tools for wiping sleeve.

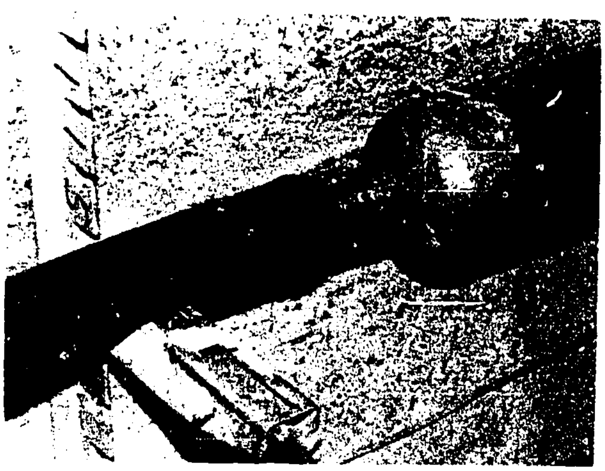
Pour the hot metal from a ladle onto the pasters first, and then allow it to splash over the joint until the joint is warm. By rapidly moving the ladle back and forth, the whole area can be tinned without burning the sleeve (fig. 11-22). Hold a catch cloth about 1/2 in. below the joint to keep the cool lead in the cloth from sticking to the joint. Do not bring the cloth up the sides of the joint at first, as you will have a lot of cold solder that would tear the cloth. Keep pouring in this manner until the metal flows freely over the joint and you have a good tin all over the joint.

You are now ready to heat the joint. Remember, to get a good wipe, the lead in the sleeve and the sheath must be almost as hot as the wiping lead—that is, almost at the melting point. Determining the correct temperature takes practice; no book can tell you just when the joint is at the right heat to start the forming process.

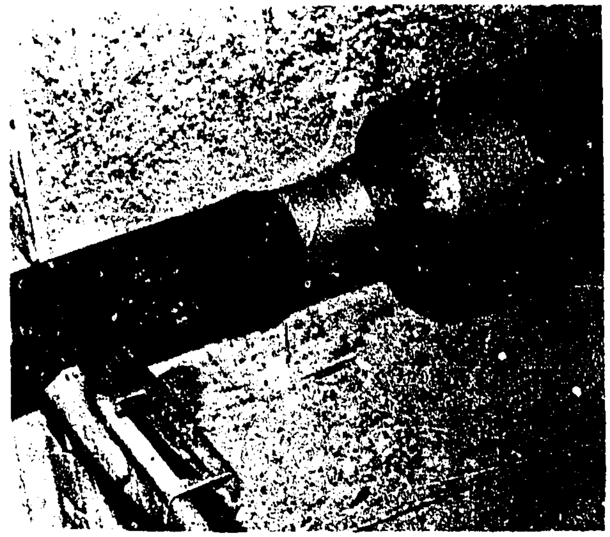
You wipe the joint with a finishing cloth. Have it handy, so you can pick it up as soon as you are ready to lay down the ladle. When you think you have the joint at the right heat, and have a ladle about 3/4 full of mushy lead, pour



73.122A
Figure 11-19.—Forming the bell with dressing tool.



73.122B
Figure 11-20.—A well-formed bell.



73.122C
Figure 11-21.—Sleeve with pasters in place.

73.123
Figure 11-22.—Heating the joint.

73.124
Figure 11-23.—Shaping the rough form.

the lead over the joint, lay the ladle in the drip pan, pick up a finish cloth in one hand and a catch cloth in the other, and start forming the joint. With the catch cloth under the joint, slide the finish cloth between the catch cloth and the lead. In this way you can start working the excess lead from the bottom to the top of the joint. Now with one cloth on each side (fig. 11-23) you can get a very good rough form.

Use the finish cloth to push the lead from the pasters back onto the rough wipe. With a little practice you will be able to have a rough form in a very few movements, but remember you have to work fast and with as little handling of the lead as possible. DO NOT PAT THE LEAD IN PLACE.

Now you are ready to finish the wipe. This should be done in three movements. First, with the finish cloth in both hands (held at the top with thumbs and forefingers, and with the middle fingers along the edges of the cloth so that the cloth is cupped somewhat to the shape of the joint), start at the bottom on the back side and wipe up to the top. Now reverse the cloth, but hold it in the same way, and wipe from bottom to top on the front side. The third motion is to wipe gently lengthwise along the cable from sheath to sleeve, to remove the excess metal brought to the top. After a few trial wipes you will find this is not as hard as it sounds. Figure 11-24 shows a finished wipe.

Let the joint cool before removing the pasters, because any movement can crack the joint while the lead is still soft. After it cools, inspect for smoothness and uniformity. One common error of a beginner is to wipe too heavily on the bottom, to the extent that the joint comes out concave instead of convex below.

Do not attempt to smooth a wipe with a torch or hot iron. If it is not right, the only thing to do is melt the wipe off with hot lead and start all over again.

If the wipe looks all right, remove the pasters and put an air gage on for a pressure test as

73.125
Figure 11-24.—The finished wipe.

73.122D
Figure 11-25.—Making pressure test on cable splice.

shown in figure 11-25. Using a hand air pump, build up pressure to read about 6 psi on the gage. If the joint holds the pressure for about 15 minutes, you can assume it is tight and remove the gage.

Filling With Compound

You are now ready to fill the joint with compound. If the sleeve does not have filling plugs like those shown in step 5, figure 11-10, cut a filling slot in the end opposite the pressure gage. Cut this slot in the shape of a crescent, and bend back the flap (see fig. 11-26). The quarter-inch punctured hole made by the pressure gage can, after the gage is extracted, serve as a vent hole while the compound is being poured in.

Heat the compound in a kettle to a temperature between 275° F and 300° F. DO NOT HEAT THE COMPOUND IN THE CAN OR CONTAINER IN WHICH IT WAS RECEIVED. Pour it in as shown in figure 11-27, until it overflows the vent hole and the slot.

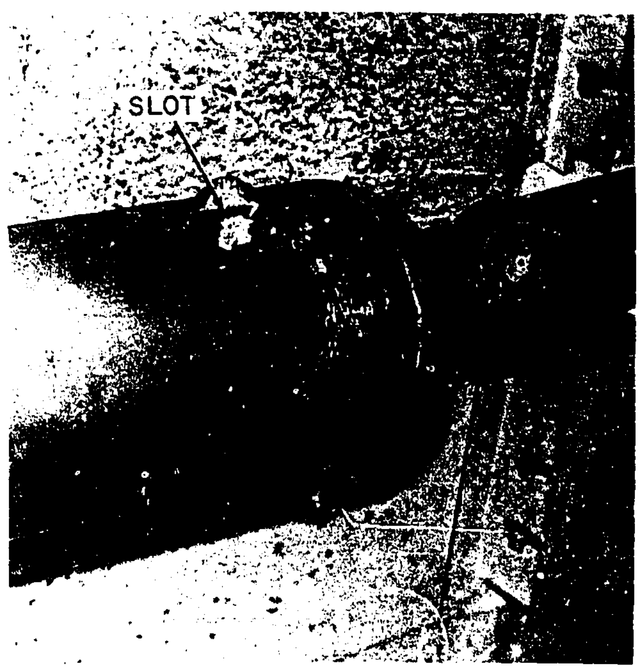
When the compound has cooled, bend the flap down and close up the vent hole as much as possible. Then put pasters around the hole 1/4 in. from the cut, and solder with the soldering iron.

Cable Splices for Higher Voltages

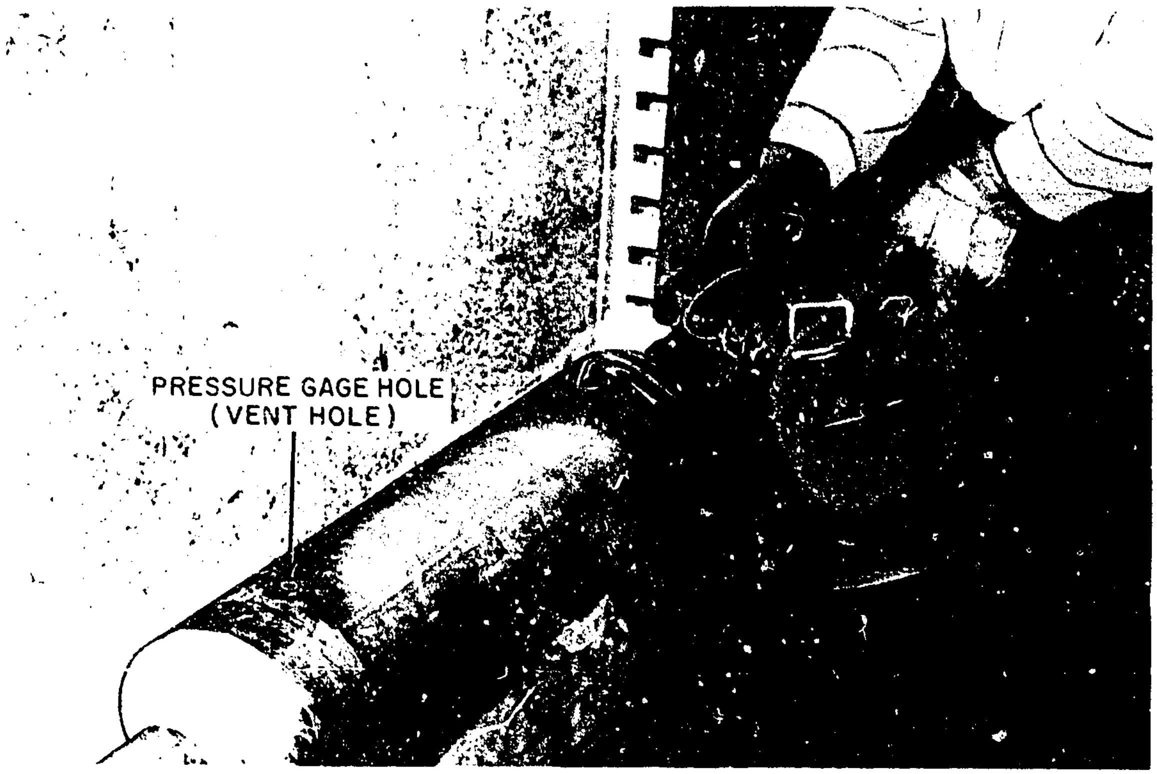
For voltages from 5 kv to 15 kv the splicing procedure is about the same as that previously described, except that there is the additional step of boiling out the joint after the splice is completely taped. For insulating splices in this 5 kv to 15 kv range, varnished-cloth tape is used.

The oil used for boiling out is taping oil, heated to approximately 230° F. Boiling out consists of pouring the hot oil over the joint, to drive out any moisture caused by damp air or by moisture on the hands.

The varnished cloth tape used for these higher-voltage splices is soaked in taping oil, and a layer of oil is put on the joint after each layer of tape. The pressure applied with each layer of tape forces out, with the excess oil,

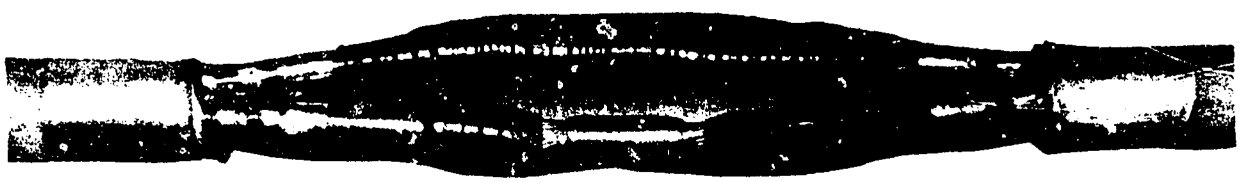


73.122E
Figure 11-26.—Slot for pouring compound.



73.126

Figure 11-27. — Pouring compound.



73.127

Figure 11-28. — Three-conductor 15-kv joint partly taped.

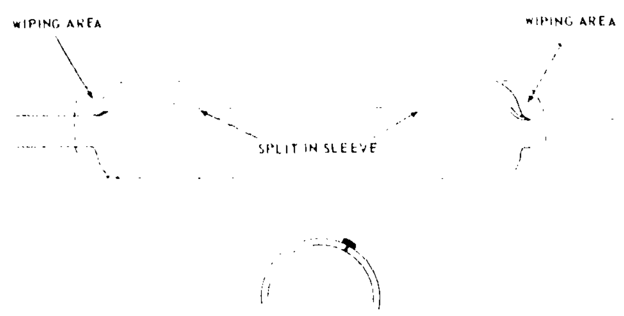
any air bubbles which might be under the tape. Figure 11-28 shows a three-conductor 15-kv joint partly taped.

Split-Sleeve Connection

In the cable splice previously described the sleeve was slid over the end of a conductor and pushed back out of the way. Sometimes the space for pushing back doesn't exist, in which case a sleeve must be split, opened out, and applied directly to the place it will finally occupy.

For this process you make up the joint and tape it for the sleeve as previously described, but without sliding the sleeve first onto the cable. You form the bell on each end of the sleeve as previously described. Next, however, you split the sleeve lengthwise with a saw, and spread it open wide enough to go around the joint, being careful not to twist it out of shape (see fig. 11-29).

Clean a space 1 in. wide on each side of the split for the entire length of the sleeve. Use



73.128

Figure 11-29. —Split sleeve.

a piece of rope to form a slack loop around the sleeve. Insert a toggle, such as a hammer handle, in the loop, and wind the loop tight enough to close the split sleeve up around the joint. Tack the two sides together with solder, to hold the sleeve closed.

Next put a paster on each side of the split, lengthwise, about 3/4 in. from the split, and one at each end. Use a hot soldering iron to melt stearine over the space between the pasters. With the soldering iron, melt a small amount of 50-50 bar solder along the split. Then use the iron to spread the solder over the area, to give the exposed surface a good tin.

Again using the soldering iron, run a heavy bead of solder the length of the seam. With a hot iron held at a slight angle, and one continuous movement, run a bead down one side of the seam, tapering from the edge of the paster to about 1/4 in. thick at the center. Move to the other side and repeat the process. When finished, you should have a smooth bead along the seam, from a feather-edge on the outside to 1/4 in. thick at the center. Then proceed to make the end wipes, air-pressure test, and compound filling of the splice as previously described.

SPLICING WITH MOLDS

Anytime that you make a splice, you will have a print (a sheet of instructions) which comes with the material. It usually is labeled "Recommended Procedures." Some linemen make the mistake of believing that a print is unnecessary; they throw it away and haphazardly make the splice. Then they blame the material if the splice is faulty. Follow the printed instructions step by step for serviceable cable splices. You may use the materials from one of several manufacturers. But the process of making the splice will be similar, regardless of which brand you use. The first step is to prepare the ends to be joined. Assume that a splice is to be made in a single-conductor cable with either neoprene or rubber insulation.

Preparation

First measure the connector sleeve from one end to the center indention. Add 1/2 inch to the measurement as allowance for expansion of the connector, and mark this distance from the end of the conductor. Shave off the insulation between the mark and the end of the conductor. Be careful not to cut or nick the wire as you remove the last of the insulation. Next, pencil the insulation to make a slope of about 45° from the end. If you are going to finish the splice with a kit using a resin or similar compound, be sure to check the length of the mold. Kit instructions direct that a cable sheath be trimmed a specified distance so that the mold will cover at least an inch of the sheath on each end. Remove the cable sheath as required. Check the conductor to see that the end is cut square, to make a good electrical connection. A conductor which was cut with a hacksaw should not be any problem. However, conductors which were cut with a tool such as a cable cutter will have been distorted. The metal will have been compressed out of shape so that there is a bulge. This bulge must be eliminated by trimming it off with a file before the conductor will slide into the connector sleeve. The mold from the splicing kit must have the ends trimmed to fit the cable. To determine the trim point, insert the cable into the mold and cut off the mold at the point where the cable stops. Slip the mold over one of the cables before the conductors are spliced. Only a split mold can be installed after conductors are joined.

Connecting the Conductors

Use a compression sleeve of the proper size and material for the conductors being joined. Slide the connector over one conductor so that the end butts against the center indentation. Using a compression tool with the correct size die, make the first press next to the center. The edge of the die should overlap the center line.

To make the next press, the edge of the die should just overlap the previous press. Continue working to the end of the sleeve in this manner. Next, insert the second conductor in the sleeve until it butts against the center. The press this side the same way, working from the center of the sleeve to the end. Tape the splice with insulating tape if required for the voltage carried by the cable.

Pouring the Compound

Center the mold over the splice and seal the ends with material provided in the kit. Wrap with tape to complete the seals and hold the mold in place on the cable. Mix the compound according to directions for the pack you are using. In cold weather, the bag of compound should be warmed to about 70° F before mixing is started. As soon as the compound is mixed (about 2 minutes), pour compound into the mold at the pouring spout. Tilt the mold slightly to eliminate trapped air. The compound acts very rapidly, so you must complete pouring with no delay.

As soon as the splice is completed, the cable should be tied securely in its permanent position with tying material approved for the cable. As an example, a cable with a lead sheath should be secured with lead tie wire. The cable can be placed in service as soon as the compound sets, which may take about 20 minutes. However, it is customary on a new cable first to make a megger test for insulation resistance and then to measure the conductor's resistance with a Wheatstone bridge. After testing, the cable may be placed in service. The cable should have a tag attached to it in a prominent place at each manhole and at both terminations. The cable tag should identify the cable by letter and/or number and should also tell the voltage at which the cable operates.

A lateral cable is similar to a service drop, except that it is underground. The cable is installed by pulling it into a duct as already described. Because a lateral is connected to an existing cable, you need to make a tee-connection splice. There are a few differences between a tee and a conventional splice. First, you need a kit with a special mold body to accommodate the tee. Next, the conductor you tap is not cut; just clean the sheath and remove the insulation for the distance required as directed by the instructions in the kit. Then, prepare the end of the lateral conductor as you would for a splice. Attach the lateral to the tapped cable with approved connectors. Be sure that the cables have enough slack so that there will be no strain on the tee. Last of all, position the mold body and fill with compound, according to the instructions for the kit you are using.

TAPECAST SPLICE

The first step in making a tapecast splice is to be sure that you have scraped the cable so that all dirt, wax, and cable pulling compounds are removed. You must do this so the resin will bond and make a moisture-tight seal. Follow the manufacturer's instructions as you remove the cable jacket and nonmetallic filler tape from the ends which you plan to splice. You ring-cut the jacket at the designated places. Be careful not to cut into the metallic shielding; unwrap it from the cable. Leave about 1 in. of the shielding exposed on each end of the cable where you have removed the jacket. Tack the metallic shielding in place with solder so that it will not unwind from around the cable.

Any time that you must solder during the making of a splice, be careful not to overheat the insulation. Later, as you wrap electrical shielding tape and use the last of one roll to which you must connect another piece, hold the two pieces away from the cable splice. Place a drop of solder on the soldering iron. Then put the iron uder the overlapped pieces of electrical shielding. Apply solder on top of the shielding over the drop of solder which you left on the iron.

You will solder a ground strap into the cable shielding if you plan to use one. Use a ground strap having the same amperage capacity as the cable metallic shielding. Next, remove the semiconducting material. Leave the designated amount (approximately 1/2 inch) exposed inside the two pieces of cable metallic shielding which you previously left exposed. Clean all of this material from the cable insulation. Use a knife, rasp, or nonconductive abrasive cloth. Be careful that you do not cut into the cable insulation.

Being careful not to nick the conductors, remove the cable insulation from the end of the conductors for the right distance (approximately 1/2 inch plus 1/2 the length of the connector). Follow the instruction measurement as you pencil the insulation at each end. Buff the tapers so that no voids remain after the joint is insulated.

Taper the cable jacket at each end smoothly and buff the taper. Finish the preparation by using a lint-free, clean cloth to clean the entire splice area. After preparing the cable, you are ready to connect the conductors.

Follow the manufacturer's directions as you use a connector to join conductors. If you are joining copper and aluminum conductors, you must use a special connector, or the two dissimilar metals will set up an electrolysis. Use a hydraulic press or crimping tool to cause the connector to make the connection. After you have the cables correctly connected, fill the connector indents with a semiconducting tape. When you use a hydraulic press or crimping tool, it leaves indents or voids in the connector. Penciling cable may also leave a void. Any void or high point tends to make electrical stress points. These points act as paths to ground. If you fill these voids and indents with semiconducting tape, there is a smooth flow of energy with no buildups. You wrap the tape over the exposed conductor and connector area, and overlap the cable insulation. Use a half-lap so that the tape will lay uniformly throughout the splice.

Next, wrap high-voltage splicing tape over the semiconducting tape and over the exposed insulation according to the manufacturer's directions. Taper the outside gradually, making the greatest diameter over the penciled insulation. Always try to half-lap when taping; this produces a uniform buildup. Also hold the tape so that it does not slant but goes straight around the cable. When it slants, voids or holes are sometimes left in the tape on the underside of the splice. Also, when you stretch the tape, you do not in any way change the tape's physical or electrical qualities. Thus, if you stretch the tape in the connector area and at the splice ends, you reduce voids.

After using the splicing tape, wrap one layer (half-lapped) of semiconducting tape over it and follow this by wrapping the splice with one layer (half-lapped) of electrical shielding tape. Overlap this onto the cable metallic shielding at each end and solder the ends of the shielding. Then cover the entire area of shielding braid with one layer (half-lapped) of plastic electrical tape. If you stretch the tape as you work, it flattens and holds the shielding braid.

Next, attach a bonding or ground wire. If the splice becomes defective, the ground wire provides a path to ground, thus preventing the electricity from traveling further down the conductor and causing a fault where it would be harder to correct. Shape this ground wire close to the tape and solder it to the metallic shielding at each end, being careful not to overheat the insulation. This provides continuity from the shielding on the other side of the splice. Use a wire which has the same amperage capacity as the shield. Next, apply the resin overcast sheath.

Wrap the entire splice with spacer tape. Extend it into the cable jacket approximately 3 inches. Start wrapping in the areas which have smaller diameters and build up to the thickness given in the manufacturer's directions, approximately 1/4 to 3/8 inch. Place an injection fitting in position according to the instruction sheet. Tape this into place with electrical tape by taping from the center of the fitting over the spacer tape and onto the cable jacket. Form a liquidtight seal. Wrap the entire splice with the electrical tape. Cover this with two half-lapped layers of restricting tape.

Because you have trapped air in the splice, you will need to vent the splice so that as the resin goes in, it can force the air out. Be careful that you do not puncture the cable jacket as you vent the splice.

Follow the manufacturer's directions closely as you mix the resin. When you have mixed the resin, clear one corner of the container or clear the center top by pushing the resin down into the lower part of the container. Tape-patch the piercing nozzle firmly onto the empty corner or top of the container. Then load the resin pressure gun. Put the tip of the nozzle through the hole in the gun cap and lock the cap in place. Then pull the nozzle through the cap and lock it to the cap by twisting slightly. Connect the nozzle to the injection fitting on the splice by rotating the gun itself so that you will not damage the resin container. When you have it connected, you start working the gun handles. This pierces the container and resin begins to flow into the splice. Inject the resin slowly. Let the resin run out of the vent until there is no longer any air escaping. Then wipe the resin off the tape and close the vent by taping it. The resin sets quickly. If the splice takes more than one container of resin, someone should be mixing the resin in one container while you inject the resin which is in the gun. When you empty the container, be sure to release the pressure on the gun so that the valve in the injection fitting can seat and prevent the resin from backing out of the fitting. Remove the gun by rotating the entire gun.

When you have removed the gun, take the cap off it, remove the empty resin container, and reload the gun with another container of resin. Continue injecting resin until the splice is full; that is, until the vent shows that the splice is filled by spilling resin. Remove any resin that has spilled before it hardens. Soap and water will remove the resin from your hands. Do not move the cables with the splice until the resin has hardened. When it has hardened, you can remove the restricting tape.

RESIN SPLICE

In making a resin splice, you prepare the cable in the same manner as for the tapecast splice except that you do not taper the cable jacket at each end. You connect the conductors in the same manner by joining them with a connector and crimping according to the manufacturer's directions, and by filling the indents with semiconducting tape. Then you apply one layer of semiconducting tape, half-lapped, over the cable semiconduction material and onto each end of the cable metallic shielding. The rest of the procedure is different because the makeup of this splice is primarily resin as its name implies.

You wrap the recommended amount of spacer tape over the semiconducting tape and the cable insulation almost to the cable semiconducting material. Start with the indents and level-wind the spacer tape across the joint. Do not stretch the spacer tape. Wrap shielding tape (quarter-lapped) over the spacer tape and overlap the cable metallic shielding at each end. Solder the ends of the shielding tape to the cable metallic shielding, being careful not to overheat the insulation. Attach the correct size bonding wire (usually No. 6 AWG is adequate) and solder it to the cable metallic shielding at each end. Shape the wire closely against the splice. Again level-wind spacer tape over the entire joint to the designated thickness, tapering it at each end. The rest of the procedure is the same as that for the tapecast splice.

Using the same method that you used for the tapecast splice, you install the injection fitting, vent the splice and cover it with restricting tape, mix the resin, load the resin pressure gun, and inject the resin. The resin type of splice requires much more resin than the tapecast type.

SAFETY

Strict adherence to safe practices is mandatory. There are three major areas of consideration in underground power distribution: (1) testing for live cable, (2) safety in and around manholes, and (3) handling of hot liquids.

TESTING FOR LIVE CABLE

Before working on a cable that has been in service, make sure that it is dead. The shorting tool shown in figure 11-30 is used for this purpose. To use the shorting tool, also known as a "lifesaver," fasten it onto the cable at the point where it is to be cut for splicing. Lead the hose to a hydraulic pump outside the manhole. Be sure no one is in the manhole when you make the test.

As you work the hydraulic pump outside the manhole, the shorting tool drives a plunger into the cable, shorting out all the conductors. If the cable is live, there will be a terrific flash, which will give you an idea of what would have happened to you if you had cut the cable with a hacksaw without prior testing.

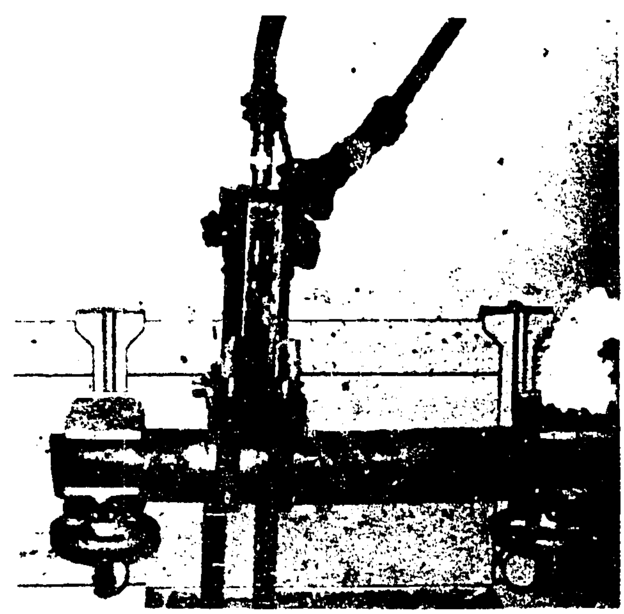


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Figure 11-30. — Lead cable shorting tool.

MANHOLES

In working in or around manholes, always ensure your own safety and that of others by first checking the ventilation. Proper safety precautions require that a gas test be made by qualified personnel before a manhole is entered. If gas is detected, the manhole must be ventilated with a power blower, and it may be necessary to reventilate periodically to maintain a safe working atmosphere. If men working below are not visible to men on the surface, someone above ground should check frequently to ensure that all is well with the men below.

When manholes are located in the vicinity of gasoline storage tanks, the check on ventilation must be extra thorough, because of the additional danger of gasoline leakage and fumes.

It goes without saying that an open flame should never be taken into or near a manhole in which explosive gases may be present.

Never use an acetylene torch underground, or even near the end of a pipe or conduit leading underground. A mixture of 3 percent acetylene with 97 percent air is explosive in a confined space. Maximum explosive effect is reached with a mixture of 7.7 percent gas and 92.3 percent air.

When you work in a manhole or other excavation, you should always make sure that it is protected by some sort of barrier or guard. Any opening that must be left open overnight should be barricaded and provided with warning lights.

Use the safety harness if you are going to work in a manhole where gas may be present. This harness is equipped with about 25 ft of manila line, fastened to a ring at the back. It is so designed as to make it possible for an unconscious man to be hauled up in nearly erect position.

HOT LIQUIDS

To avoid spillage, do not move hot liquid if its level is within 2 inches of the top of the container. Adjust to the correct level. When you carry it, your shoe soles must be clean and dry, and you should walk with a sliding or shuffling movement.

Always wear high shoes when handling hot liquids, such as melted lead. Always wear goggles when pouring melted lead, hot oil, or wiping solder. Never use leather-palm gloves when wiping lead. A leather palm glove will transfer the heat from the lead. A cotton glove won't. Always use plain cotton gloves with knitted wristlets.

In working with sealing and insulating compounds, be careful to observe the manufacturer's instructions as to temperatures. Heat slowly at first; you can increase the amount of heat later. Avoid makeshift containers for heating; always use a regulation explosion-proof kettle.

The use of a safety can for fueling furnaces reduces fire hazards. One of these cans is equipped with a pressure-release valve, so that extreme heat will not cause it to rupture.

When soldering joints, or tinning conductors, make sure that the furnace is far enough away from the manhole that no hot metal can spill into the manhole.

Using a wet or a cold ladle will cause hot compound or molten metal to spatter.

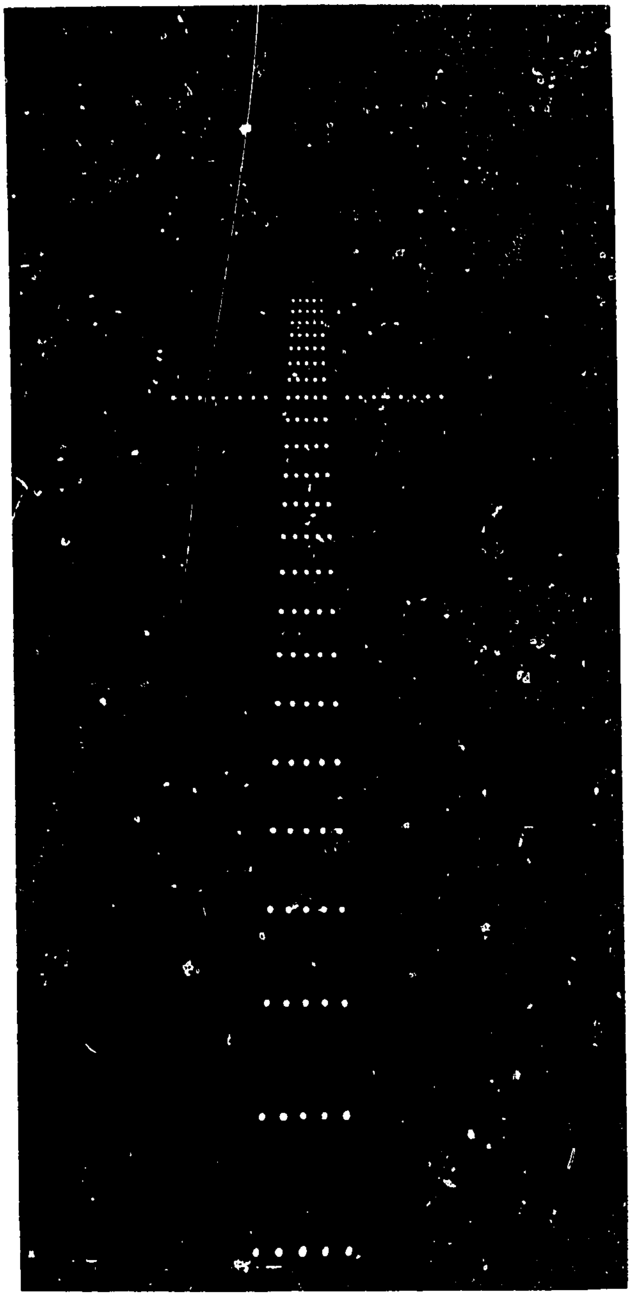
AIRFIELD LIGHTING

Airfield lighting refers to systems of illuminated visual signals provided to assist pilots in the safe, efficient landing operation of aircraft at night and during periods of restricted visibility. Airfield lighting is standardized and includes runway, approach, taxiway, and obstruction and hazard lighting, plus beacons, lighted wind direction indicators, and special signal lights. Not all these items are included in advanced base airfields. All lighting, however, except certain obstruction lighting is normally controlled from the control tower. The lighting system includes all control devices, switching gear, regulators, transformers, and all accessories necessary to produce a working facility.

STANDARDIZATION

The configuration, colors, and spacing of runway, approach, and taxiway lighting systems are uniform, regardless of anticipated length of service, mission, or method of installation. The basic color code is as follows:

Blue — taxiway lighting
Clear (white) — the sides of a usable landing area
Green — the ends of a usable landing area (threshold lights)
Red — hazard, obstruction, and non-landable area
Yellow — caution



73.326
Figure 11-31. — Approach lights in foreground.

APPROACH LIGHTING

An approach lighting system presents a configuration of lights which provide extended visual guidance toward the centerline of a runway (fig. 11-31). At airports with primary instrument approaches, the system extends 3000 ft outward from the threshold of the usable landing area. For other than primary instrument approaches, the approach lighting system extends outward only 1500 ft. Directional guidance is provided by barrettes, a crossbar, and sequential flashing lights (fig. 11-32).

Barrettes

The barrettes, or centerline bars, are composed of five spaced incandescent lights. These may be mounted flush with the runways or as shown in figure 11-33, depending upon their required elevation.

Crossbar

White crossbar lights (fig. 11-32) provide an unmistakable definite distance indication to the pilot. The bar is placed 1000 ft outward from the green threshold lights, and is approximately 100 ft in length.

Sequential Lighting

Immediate identification of the system and possible earlier view are provided by the use of sequenced flashing blue-white lights of high peak intensity. No two units flash simultaneously. Each unit is precisely timed by means of cams on a rotating shaft to flash one after another, beginning with the outermost unit and continuing to the innermost unit. Each cycle takes one-half second and repeats continuously. The resulting effect is one of a light moving at a rapid pace toward the runway. There is no appreciable pause between the innermost flash and the beginning of the next sequence. Mounting is shown in figure 11-33.

Runway Lighting

This is the principal element of airfield lighting. It provides the standard pattern of lights outlining the runway to clearly indicate side and end limits (fig. 11-32). Side limits are marked by two parallel rows of white lights, one row on each side of, and equidistant from, the runway centerline. The spacing of the lights

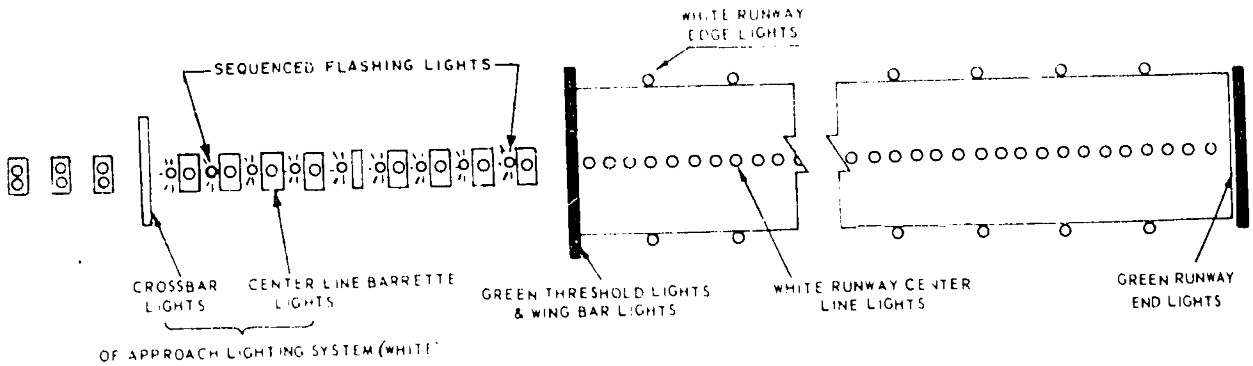


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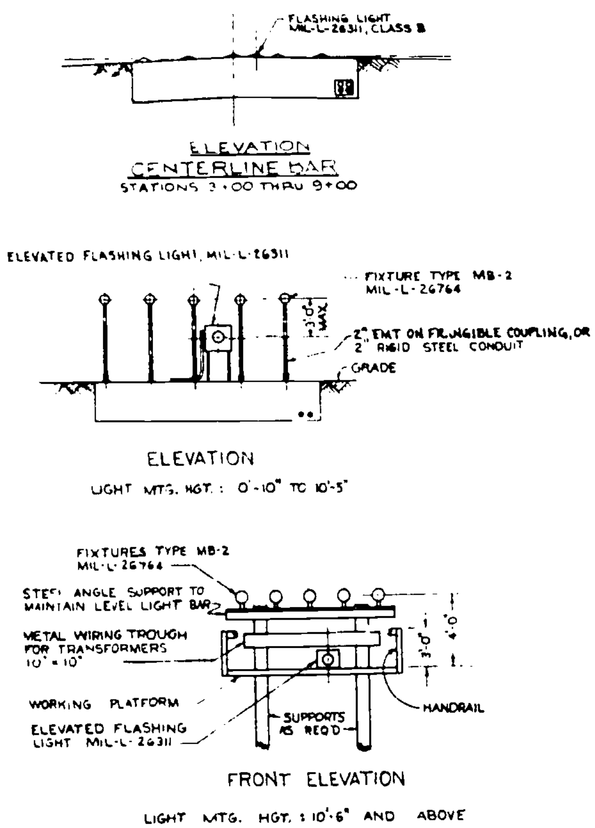
Figure 11-32. — Lights visible to an airplane moving from left to right.



73.329

Figure 11-33. — Centerline bar and sequential flashing mounting.

within the rows is uniform, and the rows extend the entire length of the runway. End limits are outlined by runway threshold lights, which are green and visible from all sides and vertical angles. Runway threshold lights are spaced along the threshold line, which is 0 to 10 feet from the end of the runway, and perpendicular to the extended centerline of the runway. A runway edge fixture and handhole installation schematic is shown in figure 11-34.

Figure 11-35 shows the plan for runway centerline lighting together with a representative wiring diagram.

On occasion, certain airports require narrow gage runway lighting. A representative wiring diagram and installation in asphalt concrete is shown for this type of lighting in figure 11-36.

Expedient Lighting

You must be resourceful when equipment is not available from the regular supply sources. Lanterns, smudge pots, vehicle headlights, or reflectors may be used to distinguish runway edges. Use of a searchlight pointed directly into the air sometimes is used as a substitute for beacon lights.

MAINTENANCE OF MARKING, LIGHTING, AND RELATED ELECTRICAL FACILITIES

Visual inspection of the airfield lighting system should be made periodically, taking into account the recommendations of component manufacturers, weather, location of the airport, numbers and nature of operations, and system complexity. In addition, regular readings should be made

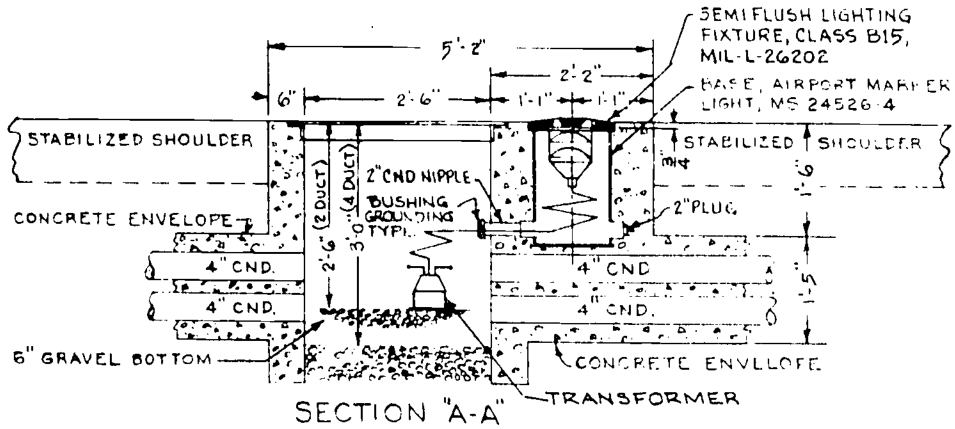
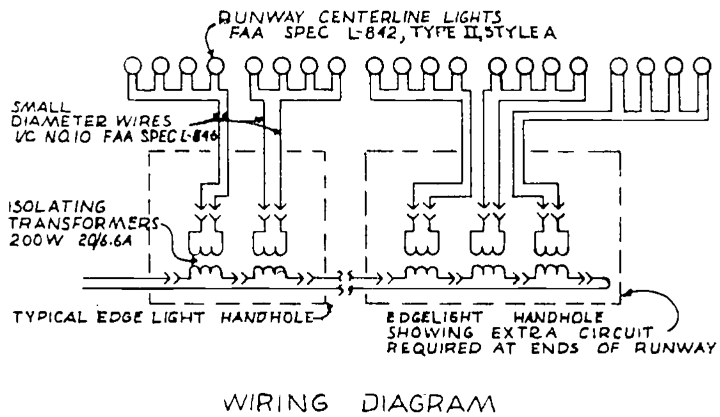


Figure 11-34. — Runway edge light fixture and handhole installation in runway shoulder. 73.331



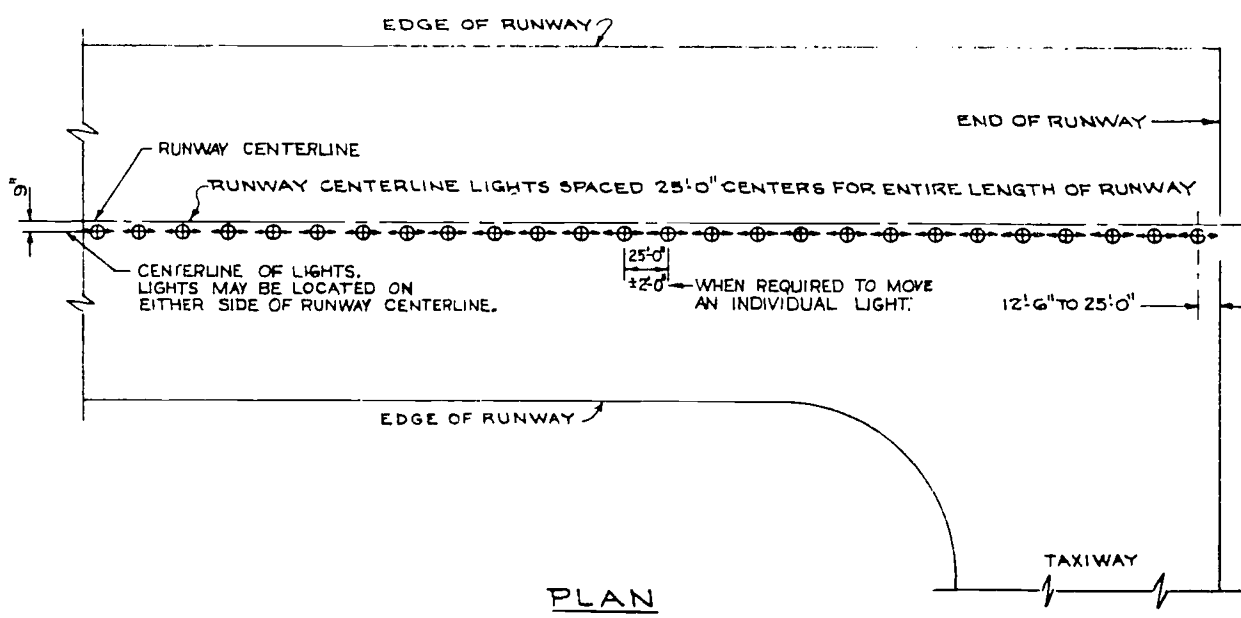
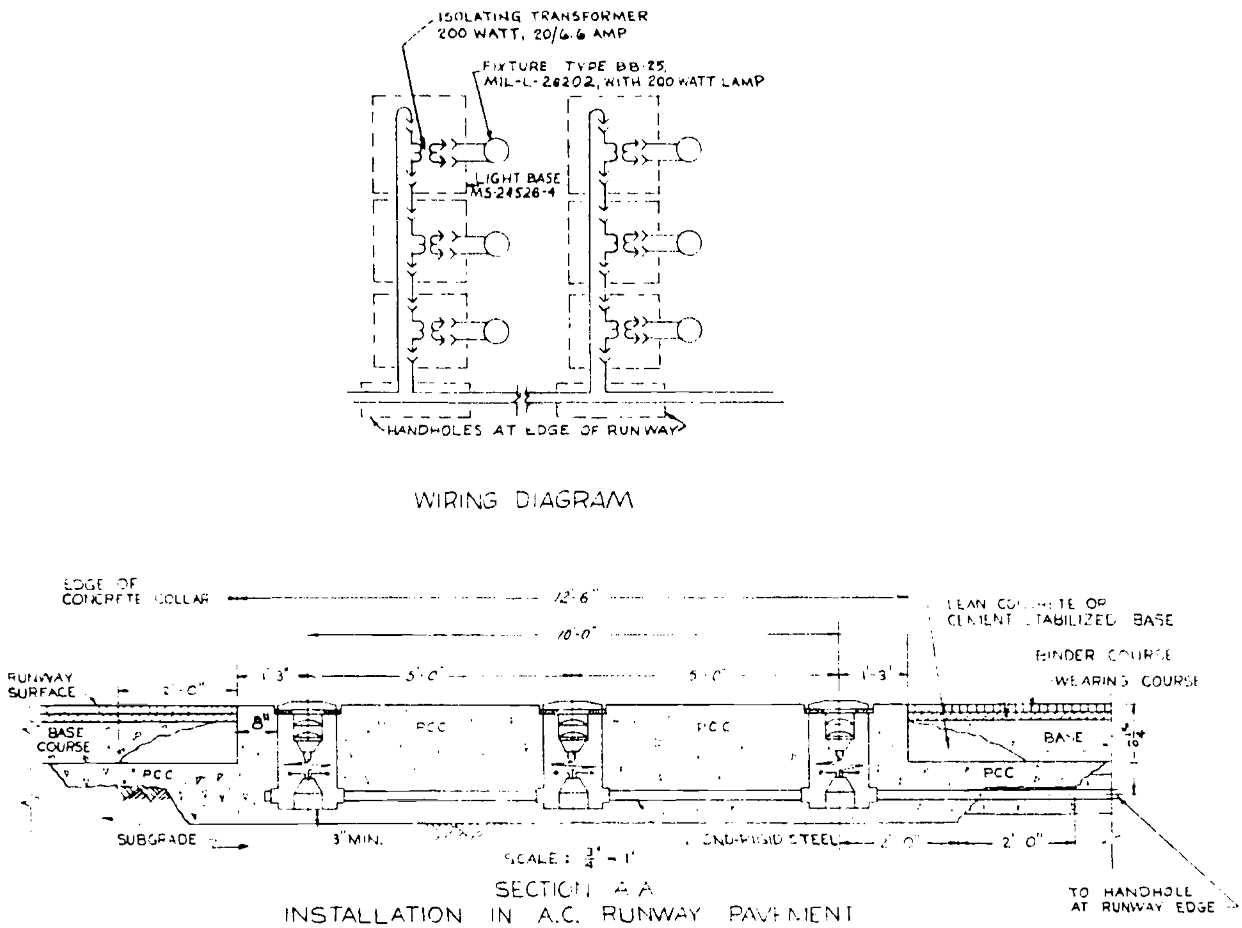


Figure 11-35. — Runway centerline lighting. 73.332



73.333

Figure 11-36. — Narrow gage runway lighting installation.

on system resistance, and other circuit tests should be made as recommended by manufacturers. Standby units should be run at regular intervals to assure readiness, if required.

Complete visual inspection of the lighting system should be made routinely at least once a week. If severe storms occur in intervening periods, resulting in excessive rainfall or lightning strikes, additional inspections should be conducted immediately thereafter. Operations of snowplows can be damaging to light fixtures, and inspections of light units should be made following such plowing operations. Circuit resistance measurements should be taken at least once each month.

As you proceed with your inspection and maintenance routines, you should look for

- Burned-out bulbs and lamps
- Broken lenses or filters
- Dirty lenses
- Vegetation obscuring lights
- Fixtures knocked over or displaced
- Damaged or insecure cones
- Evidence of lightning strikes
- Decreasing circuit resistance
- Faulty ground connections

- Malfunctioning regulators
- Water in below grade fixtures or components
- Readiness of standby power source
- Torn or damaged wind indicator
- Faded or obscure markings

When you check the circuit resistance with a megger, BE SURE TO SWITCH THE POWER TO THE REGULATOR OFF. Then you may disconnect the series cable leads at the regulator and take your resistance measurements. If you have taken periodic megger readings, you will be provided with a forecast of potential problems which will permit correction before system failure occurs.

CHAPTER 12

COMMUNICATIONS SYSTEM

In this chapter, we will discuss fundamentals f telephone communication, interoffice ommunication, and public address systems so hat you will have a clear understanding of these ystems and how to install and maintain them fficiently. Careful study of this material should nable you to do the following:

- describe a basic telephone communication ystem;

- operate a variety of advanced ase telephone equipment;

- discuss electrical theory and planning eatures of telephone line construction;

- identify components of telephone switchoards and state the purpose of each;

- install, repair and maintain a telephone ystem;

- install and maintain a public address and nteroffice communication system.

BASIC TELEPHONE SYSTEM COMPONENTS

A telephone system consists of many elephones connected together by a maze of wires. ou can understand the system better, however, f you reduce it in your imagination to a single ircuit connecting two telephones. This circuit onsists of the following components:

1. A transmitter and receiver at each of he two locations. (You use the transmitter to ransmit—that is, to send out—your voice message. You use the receiver to receive the oice message sent out by the transmitter at he other end of the line.)

2. A means of signaling—that is, activating the signal device in the subset so that the called party knows someone is calling him.

3. A source of electrical energy, required to impel the signals over long stretches of wire.

4. The wiring circuit connecting the phones and carrying the electrical energy.

In telephone lineman's technical terminology, a telephone is called a subset, and the place where a subset is located is called a substation. The wiring system connecting the subsets is called the outside plant.

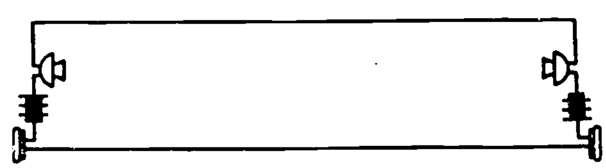
HOW THE TELEPHONE WORKS

Figure 12-1 is a wiring diagram of a basic telephone circuit. You can see that this is a series circuit from the fact that the current travels from the negative terminal of one battery back to the positive terminal of the other. A battery is the source of electrical energy which provides a constant voltage.

To get an idea of how the transmitter and receiver work, examine figure 12-2. Features of the transmitter are as follows:

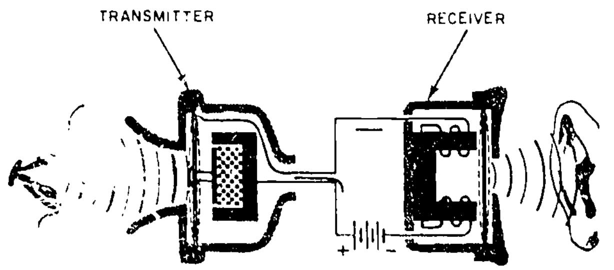
1. It contains a chamber packed with small granules or grains of carbon.

2. The carbon granules are under pressure from a movable carbon disk at one end of the chamber.



73.170A

Figure 12-1.—Basic telephone circuit.



73.168A
Figure 12-2.—How transmitter and receiver work.

3. The movable carbon disk is itself directly attached to a flexible metallic diaphragm.
4. When the diaphragm vibrates forward, it pushes the carbon disk against the granules, thus subjecting them to pressure.
5. When the diaphragm vibrates backward, it releases the pressure on the granules.

Features of the receiver are as follows:

1. It contains a U-shaped permanent magnet.
2. It contains a flexible metallic diaphragm which is slightly attracted to the pole pieces of the permanent magnet.
3. It contains a pair of coils wound on the legs of the permanent magnet.

Now trace the electrical flow in figure 12-2. The electrons leave the negative terminal of the battery, travel through the coils of the magnet in the receiver, and then over to the transmitter. At the transmitter, the electrons pass down the metal diaphragm, into the carbon disk, through the carbon granules, and then back to the positive terminal of the battery.

You can see that, given a constant voltage, the amount of current which flows in the circuit will depend on the amount of resistance in the circuit. If the resistance is high, current will be low, and vice versa.

Now, the electrons meet resistance as they pass through the carbon granules. The amount of resistance offered by the granules depends on the pressure on the granules. If the pressure is high, resistance is low. If the pressure is low, resistance is high.

As you speak into the transmitter, you set up sound waves which strike the transmitter diaphragm. The diaphragm vibrates at the same rate as the sound waves. The carbon disk vibrates with the diaphragm, and thus alternately applies and releases pressure on the granules. This in turn varies the current to the coils of the receiver magnet. The varying current varies the strength of the magnet, and this varies the magnetic attraction on the receiver diaphragm. As the receiver diaphragm vibrates, it sets up air disturbances or sound waves which are identical with the ones which are sent into the transmitter.

This has been a very general explanation of how the telephone works. The following sections deal with advanced base telephone equipment in more detail.

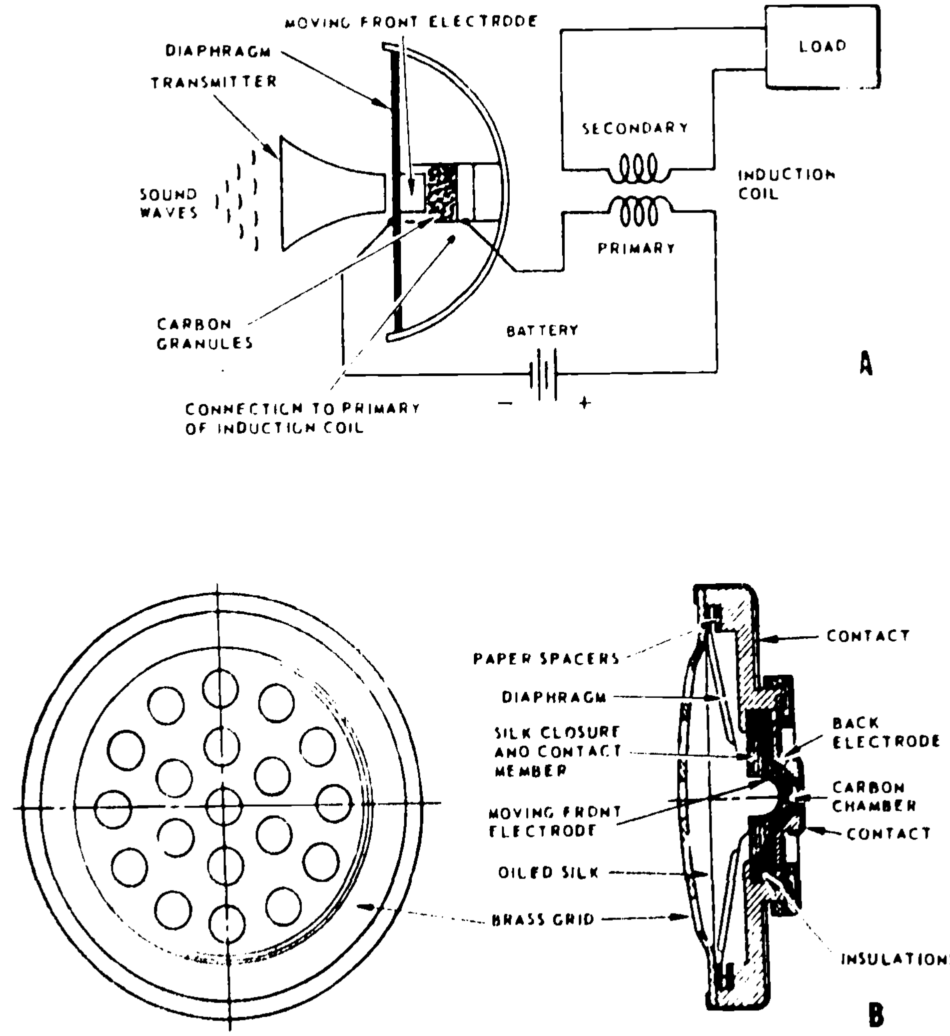
TRANSMITTER

The basic function of the transmitter and the way it performs that function were previously described. However, energy losses during transmission over the wires would naturally cause the useful energy at the receiver end to be less than that of the initial sound waves at the transmitter. Therefore, the circuit of the transmitter must be capable of amplifying the original energy of the sound waves in accordance with the line distance the energy must travel.

Various telephone subsets with carbon transmitters provide this necessary energy increase by the use of an induction coil, a device that functions like a transformer. The battery, the carbon, the diaphragm, and the induction coil compose the basic circuit, as illustrated in view A of figure 12-3. View B shows the construction of the carbon transmitter.

A bell-shaped chamber is packed with carbon granules, which have uniform contact with two gold-plated electrodes. The diaphragm is of flexible aluminum alloy, supported by paper spacers. The negative terminal of the battery connects with the diaphragm, which in turn rests against the chamber of carbon granules. The other side of the carbon chamber is connected with the primary of an induction coil. The return of the primary to the positive terminal of the battery completes the circuit. You can follow all of this in figure 12-3, view A.

Sound waves entering the diaphragm cause it to vibrate, and the moving front electrode exerts a varying pressure on the carbon. As the state of compression of the granules varies, the



73.167

Figure 12-3.—Carbon transmitter. (A) Circuit; (B) Construction.

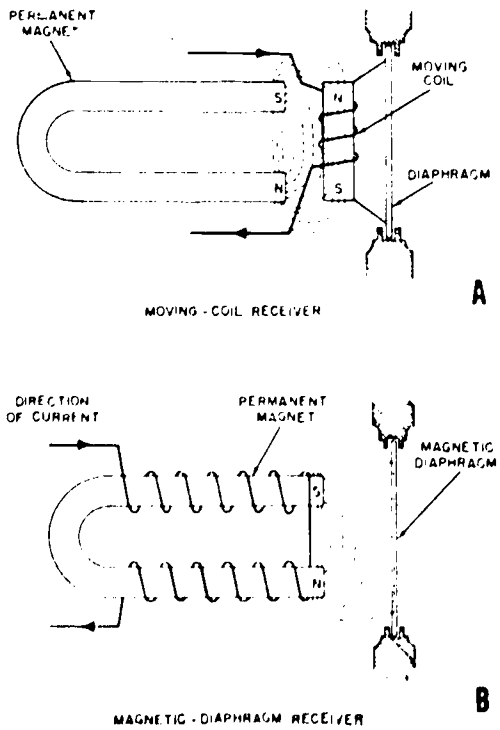
resistance also varies. As compression increases, resistance decreases, and the current in the circuit increases.

For example, if the battery has an emf (electromotive force) of 6 volts, and the carbon granules have a normal resistance of 300 ohms, the average value of current flow will be 20 milliamperes. When the diaphragm is made to vibrate (by speaking into it), the compression on the carbon granules may decrease resistance to 200 ohms, and current will consequently increase to 30 milliamperes.

On recently developed transmitters, sound waves intended to actuate the diaphragm should strike it at right angles, and from a very short distance. If the sound originates too far from the instrument, it will enter the transmitter from both the front and the back of the diaphragm, and thus will equalize pressure on the granules. The effect of these distant sounds, then, is practically zero. This type of transmitter has great value for military use, because it successfully cancels out background noises.

RECEIVER

Two common types of receiver, the moving-coil type and the magnetic-diaphragm type, are shown in figure 12-4. Both types are permanent-magnet devices, but the moving-coil type operates



73.168B
Figure 12-4.—Moving-coil and magnetic-diaphragm receivers.

on the same principle as a motor—that is, as the current in the moving coil varies, the magnetic field around the coil varies. As a result, the coil vibrates and causes the diaphragm to vibrate, which generates sounds of the same wave form and frequency as the current in the coil.

The magnetic-diaphragm type operates by variation of the strength of the magnetic field. Variations in amplitude and frequency of the magnetic field cause corresponding variations of motion in this diaphragm. This is the most common type used in telephone systems.

LOCAL BATTERY AND COMMON BATTERY CIRCUITRY

The electrical energy for a telephone circuit may come from a central source of power, or it may come from a local source, such as a dry cell, or a combination of dry cells.

When dry cells are used as the source of energy, the telephone installation is known as a local battery set. The cells provide the current for talking circuit, but signaling is usually produced by a small hand generator.

When a common or central source of power is used to provide energy, the system is called a common battery system. The source provides both signaling current (by means of a ringing machine attached to the power source) and current for the talking circuit.

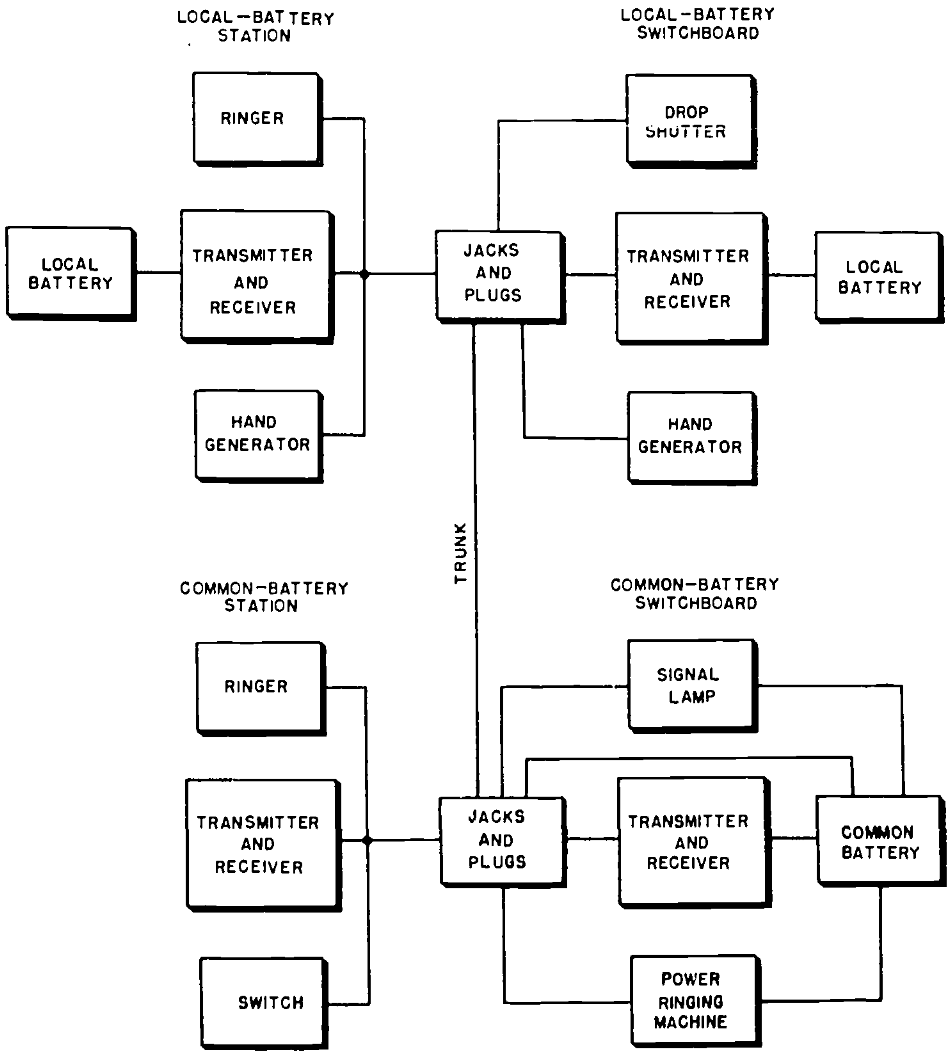
A manual installation at an advanced base may be the local battery type, the common battery system, or a combination of both. Where local battery sets are used, telephones may be connected directly, but connections are usually made through a switchboard.

Where a local battery system is established in the first days of occupation of an advanced base, it is possible to interconnect the switchboard of this emergency system with the switchboard of the common battery system, as soon as the latter has been established. A simple diagram for this type of interconnection is shown in figure 12-5.

The difference between a local battery and a common battery system is more than just the difference in power source. The location of the power source is also different. A local battery system has a battery (either one dry cell or several) at each telephone station. A common battery is centrally located, and serves all the stations of the system.

The common battery cannot serve all the stations unless the stations are in parallel with each other as far as direct current is concerned, and the battery is connected across the line instead of in series. The common battery, consequently, maintains a fairly constant voltage, and gives a more uniform signal than the local battery. This signal on the switchboard is automatic when the receiver is lifted; there is no necessity for the hand generator.

Advantages of the common battery system are that some of the equipment is simpler and cheaper, and inspection can be made at a single point to see if the cell or other power source is functioning. However, there is the disadvantage that the common battery system requires much better line construction than the



73.169

Figure 12-5.—Local battery system connected to common battery system.

local battery system needs. The switchboard equipment, too, must be more elaborate.

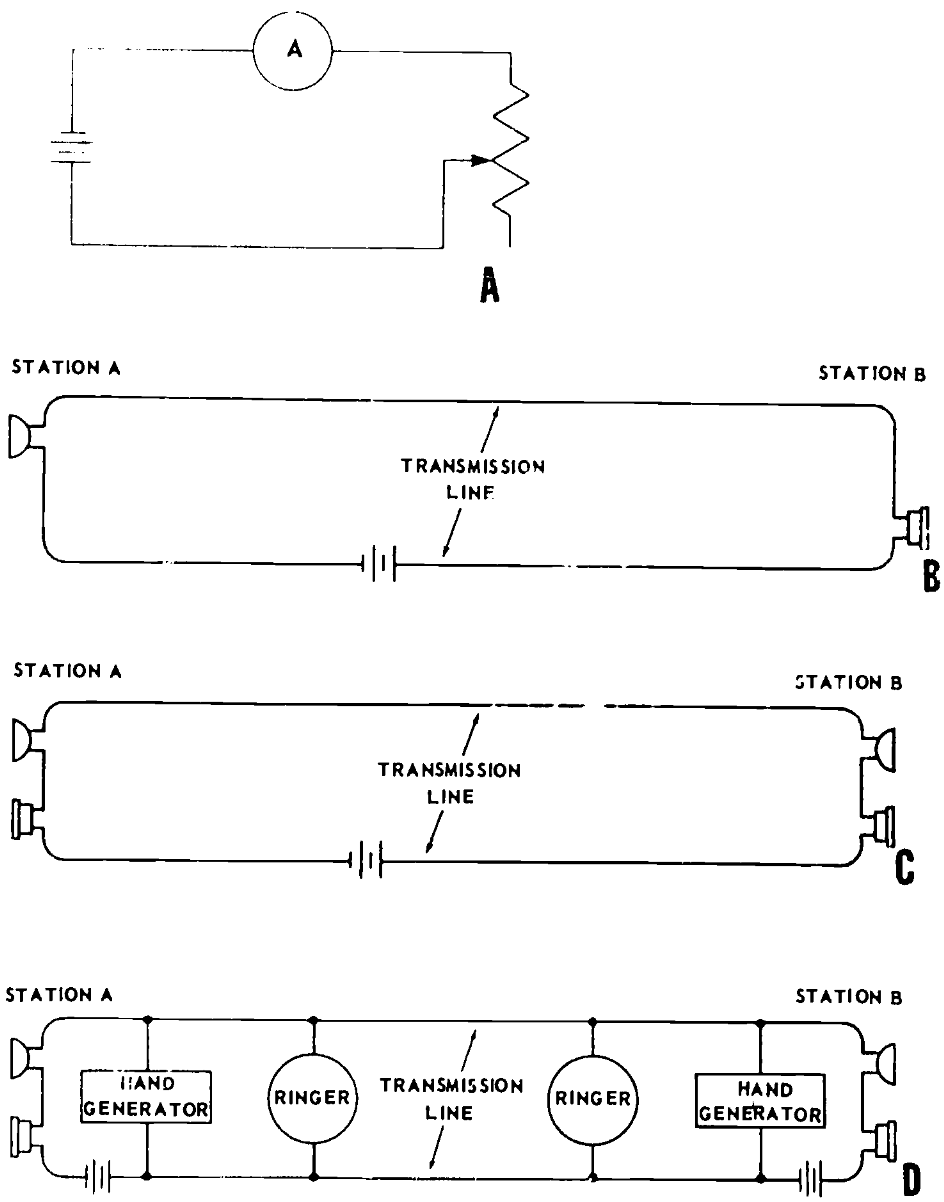
The hookup of the components of a simple telephone system are illustrated in the four drawings shown in figure 12-6. View A is a simple schematic diagram, showing the negative battery terminal connected to the ammeter, the ammeter to the resistor, and the circuit completed by connection from the resistor to the positive terminal of the battery.

View B shows the most elementary form of telephone circuit; a transmitter connected to a receiver. This would, of course, permit oneway conversation only.

View C shows a system which permits two-way conversation, but lacks a signaling device for alerting the receiving end to a call.

The circuit shown in view D, using dry cells alone, has a hand-generator-operated signaling device. However, line resistance, which increases with line length, would make this circuit practicable for short distances only.

What is lacking here is an induction coil—that is, a transformer device (primary coil and



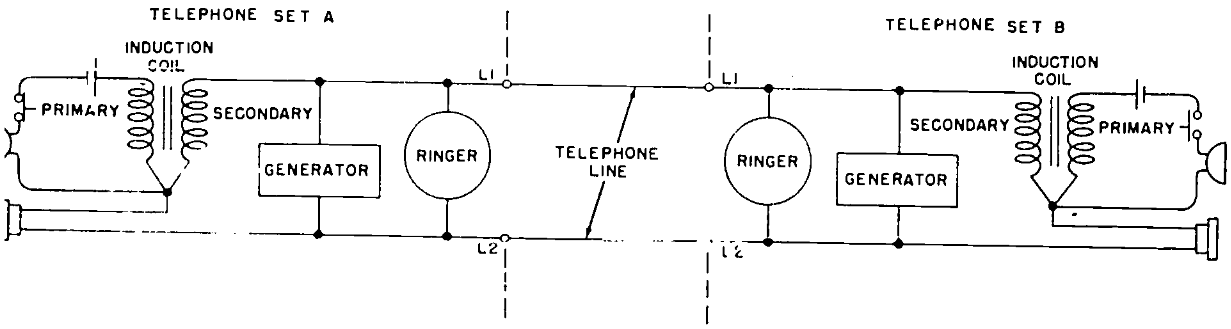
73.170

Figure 12-6.—Basic telephone circuits.

secondary coil) for stepping up the energy by magnetic induction. Putting a varying current in one coil induces an a-c voltage in the other, the value of the induced voltage depending on the ratio between the number of turns in the two coils and the rate at which the current changes.

Figure 12-7 shows induction coils in a circuit containing two local battery stations. Notice how, in each station, the primary coils are connected to the transmitter and to the battery. The secondary coil is connected to the receiver and to the line wires.

When you speak into the transmitter at set A, your voice causes a varying current to flow in the transmitter circuit. As this current passes through the primary coil, it produces an expanding



73.171

Figure 12-7.—Induction coils in circuit between local battery stations.

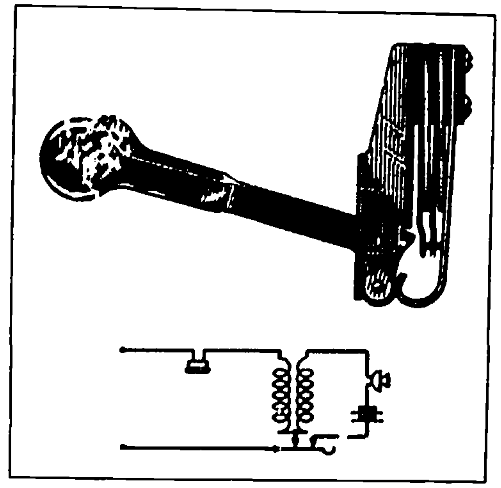
and contracting magnetic field. This field cuts the turns of the secondary coil, and induces a current in the secondary circuit. The receiver at set B reconverts this current to sound waves.

The secondary coil of the induction coil usually has more turns than the primary. Additional turns on the secondary coil give the same effect as a step-up transformer, and operate to cut down power losses.

Note that in the circuit illustrated in figure 12-7 there is a common connection between the primary and the secondary coils (a situation that does not exist in an ordinary transformer). This connection, however, does not affect the transformer action of the induction coils. It serves the practical purpose of reducing the necessary number of handset cord conductors. This common connection can also be used for such special circuits as the anti-sidetone circuit, which reduces the passage of voice currents from transmitter to receiver IN THE SAME SET.

HOOK SWITCH

In desk telephone subsets a hook switch (fig. 12-8) is used. The hook or cradle holds the receiver when the telephone is not in use. When the receiver is lifted, a hook spring forces two thin leaf springs together. Small buttons on the ends of the springs make the contact. The opposite ends of the springs are connected to the circuit, one spring being connected to the transmitter circuit, and the other to the incoming line. Thus both receiver and transmitter are put into action. Breaking the contact be-



73.172

Figure 12-8.—Hook switch.

tween the leaf springs (by putting the receiver back on the hook) also breaks the talking circuit.

MAGNETO GENERATOR

A small hand-operated generator is used in telephone circuits to provide signaling service. The generator is a magneto—because the magnetic field is provided by permanent magnets rather than by exciter coils. The generator is cranked by hand, and at a normal cranking speed it will develop an emf of from 80 to 90 volts, at frequencies of 16 to 20 hertz. Increasing the cranking speed will, of course, increase the generated voltage and the frequency.

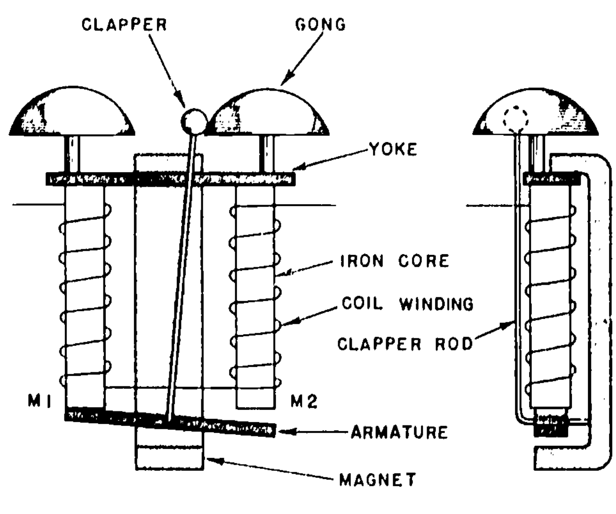
A spring switch actuated by the shaft of the crank handle provides a make-and-break contact, in that it connects the generator onto the line, and removes the bell from across the line.

A recently designed hand generator is provided with a dial, and you can either spin the dial or crank in the usual fashion. The crank is pivoted, and fits into a compartment on the dial face when not in use. The generator unit can be removed from the equipment and disassembled for servicing.

RINGER

The signaling device in a telephone set is usually a ringer—that is, an electric bell operating on low frequency (20 hertz) and powered by the hand generator. Figure 12-9 shows the operating principle of a ringer.

Two electromagnets, formed of coils wound on soft iron cores, are permanently joined at the upper ends by a yoke of soft iron. An armature is placed under the cores of the electromagnets, and pivoted at the center. A U-shaped magnet is secured at one end to the yoke that joins the electromagnets. The opposite end of the U is bent around the armature, but does not actually touch it. The armature carries a clapper rod which can vibrate between two gongs mounted above the yoke.



73.193

Figure 12-9.—Simplified diagram of a ringer.

When there is not current in the ringer, the magnetic lines of force are distributed evenly between the cores, and the armature is in balanced position. Alternating current through the ringer upsets this balance. By applying the left-hand rule for coils (explained in Basic Electricity) to M1 and M2 in figure 12-9, you observe that the magnetic polarity of M1 is opposite that of M2. The magnetic polarity of each will reverse every half-second, while the magnetic polarity of the permanent magnetic remains constant. Therefore, the lines of force of the permanent magnet are attracted to a different electromagnet every half-second. This causes the armature to vibrate rapidly between M1 and M2, which in turn causes the clapper to strike the gongs.

TELEPHONE SYSTEM DESIGN

An advanced base telephone system uses field wire on small installations and field cable for large installations.

Many of the problems which occur in relation to the installation and maintenance of military telephone systems are connected with increasing talking range, with the overloading of lines, and with interference which occurs when there is a transfer of electrical energy from one conductor to another. To understand these problems, you must have some knowledge of the principles of electrical theory as they apply to communications systems.

The electrical characteristics of communication transmission lines involve (1) power loss which increases with electrical length of line, and (2) distortion and interference caused by reaction of one line to a nearby line. These characteristics are complex and highly technical. Only the highlights can be discussed here.

ELECTRICAL LENGTH

The electrical length of a transmission line is not a linear dimension, but the relation between the length of the line (which is a linear dimension) and the wave length of the transmitted signal. It is this fact that makes electrical length an important factor in operating conditions.

A short line is one in which the length of the line is considerably less than the wave length of the transmitted signal. A long line is one in which the length of the line is equal to, or longer than, the wave length of the transmitted signal.

The wavelength is the ratio between the velocity of the electrical wave and the frequency of the signal. This may be expressed in the following formula.

$$\text{Wave length} = \frac{\text{Velocity}}{\text{Frequency}}$$

ATTENUATION

The general term for power losses along a transmission line or network is "attenuation." In an open-wire pair, attenuation depends on (1) the size, spacing, and material condition of the conductors, (2) the kind, number, and condition of the insulators, and (3) the frequency of the current. Under ordinary conditions there is less attenuation in an open-wire line than there is in cable or field wires.

LOADING

The talking range of a cable or field wire used for military communication is frequently increased by a procedure called loading. As applied to a transmission line, loading means increasing the series inductance of the line by adding external inductance. Lumped loading means the addition of loading coils with relatively high inductance at regular intervals along the line. This is the method most commonly used at a [illegible].

Continuous loading means wrapping the cable conductor with tape or wire made of magnetic material. This wrapping distributes the inductance continuously along the line and results in improved performance. Continuous loading is used on submarine cables, because lumped loading would subject them to excessive strain at the points where loading coils were inserted.

INTERFERENCE

Interference is a serious problem on telephone lines. It may result from lightning or other natural electrical disturbances in the atmosphere, or it may be caused by nearby power sources such as powerlines, railway facilities, or other communication circuits. When two or more telephone talking circuits operate in parallel with each other a transfer of electrical energy may cause crosstalk. When telephone lines run parallel to powerlines for a considerable distance, the transfer of electrical energy causes noises on the telephone lines. Battery chargers used to maintain storage batteries in a common battery system may cause a humming noise.

Interference may be kept to a minimum by maintenance of lines, transposing wires, balancing line capacitance, and using repeating coils, and noise filters. However, careful installation of lines and regular inspection of splices, joints, insulators, and other line equipment also helps to keep down noise. Methods and techniques for minimizing interference by proper installation were discussed in the chapter on the overhead distribution.

Capacitive coupling between adjacent telephone wires can also cause crosstalk. This effect can be reduced by transposing wires in the cable at points where one length of cable is spliced to an adjacent length of cable. Another method of reducing capacitive coupling is to connect the wires on one end of a short length of a twisted pair to the cable pair, leaving the wires on the other end of the short length unconnected.

In emergency installation, 1-wire ground-return telephone circuits may be used in conjunction with a 2-wire circuit. A 1-wire circuit is especially sensitive to inductive interference from adjacent circuits. Such interference can be greatly reduced by connecting the 1-line circuit to the 2-line circuit through a repeating coil.

Low-pass filters may be used to remove hum caused by battery chargers and similar equipment. These filters consist of a series of choke coils and shunt electrolytic condensers of rather large capacity. By filtering the output voltage, they remove the higher frequencies that lie in the voice frequency range.

TRANSMISSION SYSTEM PLANNING

Transmission lines used in military telephone installations may be field wires, open wires, or field cable.

Field wires consist of simple pairs of insulated wires twisted together. As a rule, you will use field wire chiefly for emergency and temporary installations. Transmission losses are so high that field wire lines must be confined to short lengths.

Open wires are parallel single bar conductors strung on pole crossarms.

A telephone cable consists of one or more pairs of wires, with each wire individually insulated. Field cable is available in 5-pair and 10-pair cable, color coded, rubber insulated, copper jacketed, and equipped with a connector on each end.

Begin planning by making a preliminary survey of the number of overhead and underground crossings the line must make, of the streams it must cross, of the general character of the terrain, and of any possible obstacles in the way of future maintenance work.

In routing, consider points where the lines might be damaged by construction operations, remembering that about everything at the base will be under construction at this time. When you have mapped the route along which the lines are to be laid, choose the wire or cable according to the type of line to be built.

FIELD WIRES

In laying field wire, select the shortest and the most effective route. At advanced bases, savings of time and of material can be very important factors. Surface line construction is the quickest type, but is vulnerable to weather conditions and mechanical damage. If the wires are surface-laid, they should be laid loosely, to minimize any damage from bombing.

Test the reels of wire for continuous circuit. Install test stations at exposed points on the wire line—for example, where circuits diverge (or may diverge with future expansion of the system), and at the end of a line that does not terminate in a switchboard. In the actual laying of a line, you will find additional points at which it will be desirable to set up test stations.

Use overhead lines near headquarters and camp areas, and at road points where it is likely that traffic will be diverted from the road.

Trees can be used as supports for overhead wires, but they may sway during high winds. To offset this, a slightly more-than-normal sag should be provided. In some cases you may have to use slings to give intermediate support.

If field wire is placed on poles carrying bare conductors, it must be strung below the lowest bare conductor. Precautions must be taken to ensure that, in swinging or otherwise, telephone wire will not contact the bare conductor.

At junctions between overhead and surface lines, tie the wires securely to the bottom of the support and tag them. Where there are long stretches of overhead lines, install test stations at junctions with other types of construction.

OPEN WIRES

For open wire installations, you will use steel wire, hard-drawn copper wire, or copper-clad steel wire, diameter from 80 to 165 mils. Two wires constitute a line.

The conductors are strung on electrical insulators mounted on the crossarms of telephone poles. As each basic telephone circuit requires two wires, you will have to mount quite a number of bare conductors on the crossarms. Keep each conductor in place by tying it to an insulator. Standard spacing distances are 8 in. for a single pair of wires, 10 to 12 in. when more than one pair are strung.

The procedure for stringing telephone wire is similar to that for stringing powerline wire. You should know the main operations (reeling out the wires, raising wires to crossarms, tensioning, and tying in) by now.

TELEPHONE CABLE

Because of the numerous wires that are carried in a cable of nominal cross section (as, for example, 1 1/2 in. in diameter), there are certain disadvantages in using cable. The voltages carried are low, which means that a single wrap of dry paper is insulation enough for each wire. However, this insulation is so thin, and the wires are so tightly packed, that a very small amount of moisture can produce a short.

TYPES OF TELEPHONE CABLE

The following are commonly used types of telephone cable:

1. Exchange cable is the outside cable of a central office that furnishes the facilities for sending out and receiving calls through local switchboards.

2. Toll cable is a quadded or nonquadded conductor (the term "quadded" means that all

or some of the conductors are arranged in quads, or groups of two pairs) used for communication between widely separated local exchanges.

3. Trunk or tie cable is used primarily for connecting exchanges which are fairly close together.

Post or administrative cable forms part of a fire control communications system. Target range cable is used exclusively on a target range, and is not connected to any other system. Fire alarm cable is used exclusively in a fire alarm system.

OVERHEAD CABLE LINE

Open wire needs no intermediate support between poles. Telephone cable, however, must be supported between poles by a series of metal rings which are suspended from a galvanized steel wire called a suspension strand or messenger, or the cable is held to the messenger by a process known as spinning or spun cable. A small wire (or wires) is spun around both the cable and the messenger by a machine called a cable lashing machine.

Suspension Clamps

The first step in stringing the messenger is to provide support at each pole by installing a suspension clamp. One of these clamps consists of two metal bars which can be clamped together by tightening a nut and bolt assembly. An overhanging lip on one of the bars forms a groove that holds the suspension strand.

Stringing Suspension Strand

When suspension clamps have been mounted on all the necessary poles, you can string the suspension strand. As the strand is unreeled, it is carried up each pole, and placed in the suspension-clamp groove. The clamp nuts should be tightened only enough to keep the strand from falling out.

The next step is to pull the suspension strand to the proper tension or sag. Leading the pulling line through a snatch block (block on which the side strap can be opened for inserting a line or wire when the end is not available) set at the top of the pole will prevent the suspension strand from being pulled out of the grooves on the clamp.

After the suspension strand has been pulled to the specified sag, it must be dead ended. You can terminate the strand at the eyebolt used for the guy wire. Thread the free end of the strand through a thimble in the eyebolt, then double it back and clamp it to the main part of the strand, or use a preformed dead end grip.

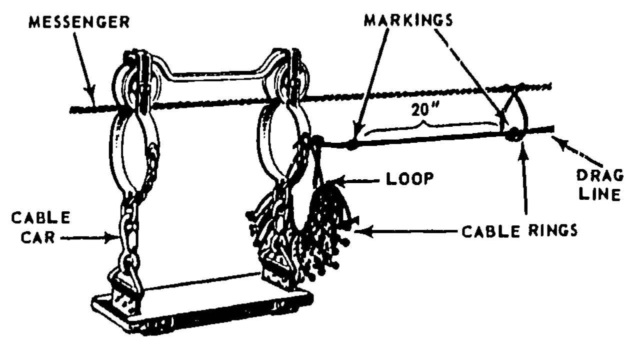
The last step in the installation of suspension strand is the tightening of the suspension clamps. At first you tightened them just enough to hold the strand in the groove. Now they must be fully tightened. It is best to start at the middle pole and work toward each end in turn.

Cable Rings

One method of fastening the cable to the supporting suspension strand is to use cable rings. To string these rings on the suspension strand you will probably use a cable car like the one shown in figure 12-10. A loop of wire attached to the car holds the rings. A drag line, marked with the ring spacing as shown, is left threaded through each ring as the car passes along. The drag line then serves as a pulling-in line when you are ready to pull the cable through the rings. If you line the reel up carefully with the suspension clamp, the cable should pull smoothly through the rings.

Lashings

Instead of being suspended on rings, the cable may be lashed to the suspension strand. First the cable is brought up to the strand. Then the two



73.175

Figure 12-10.—Cable car for placing rings.

are lashed tightly together with a spirally wound wire using a cable lashing machine (fig. 12-11).

To bring the cable up to the strand, you can use temporary cable rings, which can be removed as soon as the lashing is applied. An alternate method is to mount the cable reel on a truck, and pay the cable up to the suspension strand through a cable guide (shoe) to which the lashing machine is attached.

UNDERGROUND TELEPHONE LINE

The advantage of direct burial of telephone cable, a method frequently used in laying field cable, lies in the fact that an underground system is usually much easier to construct than an overhead system.

Protection against corrosion and damage is provided by placing the cable in ducts, a method which also facilitates pulling in and replacing cable when necessary. Manholes and splicing chambers constructed at intervals along the line serve as convenient points for inserting cable in ducts.

Make the trench no wider than necessary, but deep enough to allow 18 inches of earth cover over the cable. Remove any rocks that might damage the cable. Where a reel runs out, bring the end of the wire into a splicing chamber, or up to the ground surface, to splice it. Backfill excavated earth with a grader or bulldozer.

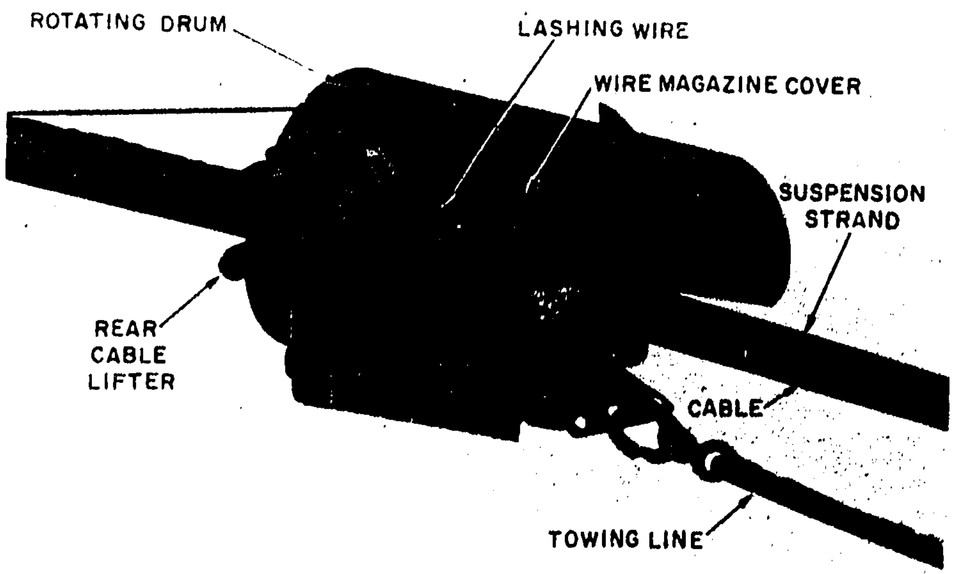
Again as with underground powerline ducts, have the trenches slope toward the manholes for drainage. Make sure that ducts have been cleaned of dirt or concrete before pulling cable through. Push a rodding tool through from one manhole to the next. Attach a threading wire to the last section of rod in the rodding tool, and a rope to the threading wire. When the rope appears in the manhole, fasten the end to the pulling source of power. Fasten the other end to a cable grip on the cable to be pulled through.

OUTSIDE TERMINALS

In carrying telephone wires from switchboard to subsets, there will be numerous places where the cable will have to be spliced. Methods of splicing telephone cable are described in chapter 13.

Terminal boxes are mounted at convenient points along the pole lines—two or more boxes must be used, if the number of telephones to be installed exceeds the number of terminals in a single box.

The appropriate wires are brought out from the cable and connected into these boxes.



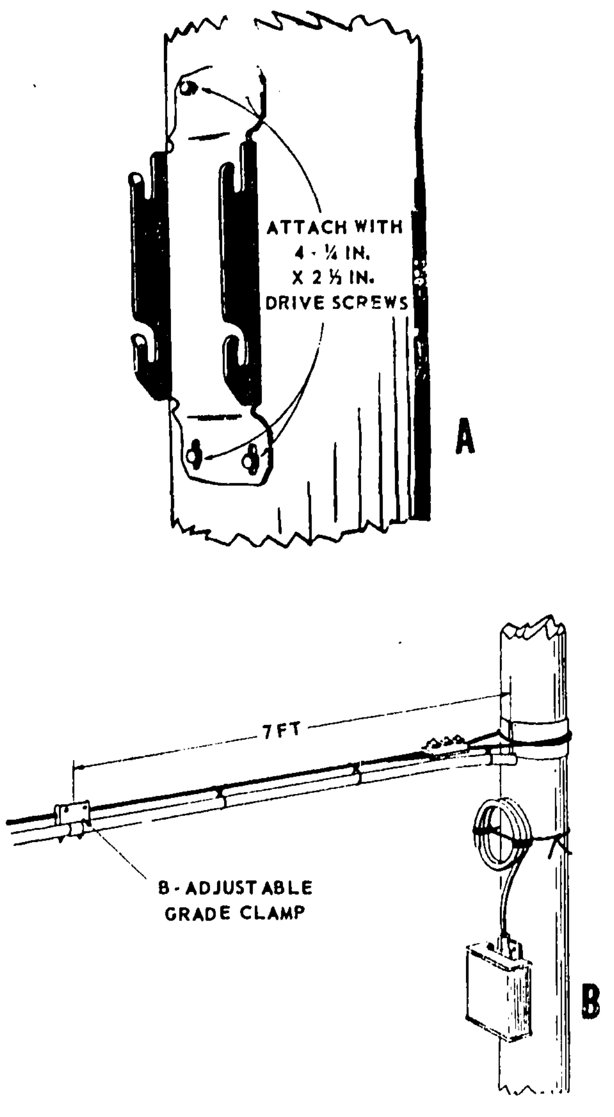
73.337

Figure 12-11.—Cable lashing machine.

Outside drop wires are then installed to lead from the terminal boxes to the substations.

Mounting Terminal Boxes

Mounting terminal boxes on poles is a job commonly given to the CECN. A can bracket is first attached to the pole, about 24 in. below the main cable, by four screws. The terminal box is then placed in supporting notches in the bracket. (See fig. 12-12.)



73.177
Figure 12-12.—(A) Can bracket for pole-mounted box; (B) Box installed in bracket.

Terminal Box Panel

Inside a terminal box there is a panel fitted with binding posts, nuts, and washers. A short length of lead-sheathed cable is attached at the back of the box. Drop wires from the individual subsets are attached to the binding posts.

Figure 12-13 shows how connections are made at the panel of a terminal box. As soon as the wires in the cable stub are spliced to the wires in the main run of cable, you will have a completed circuit from main line to subset. In figure 12-12 you can see the cable stub coiled and ready for splicing to the main line. Tapping the main line, and calling the wire chief or switchboard operator to assure proper line number and subset operation, is usually the last step in telephone installation.

TELEPHONE SWITCHBOARDS

Connecting a large number of telephone stations directly to each other would require an enormous maze of wires. To reduce the amount of wiring and to simplify the wiring arrangement, a switchboard is installed in the system

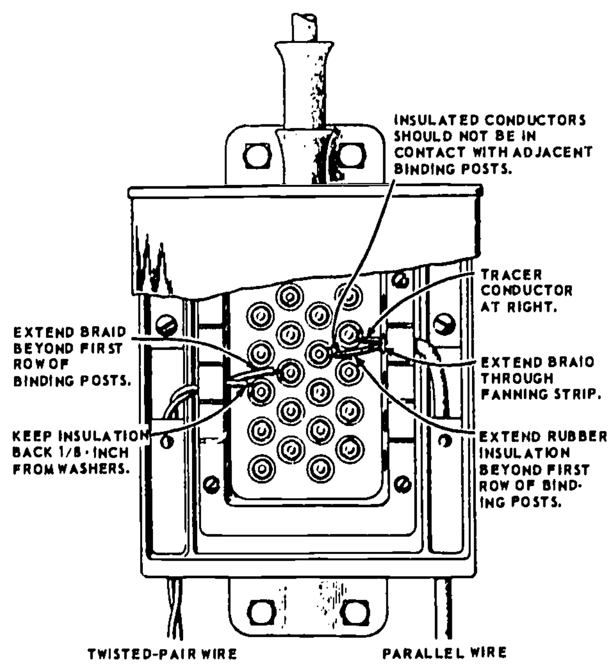


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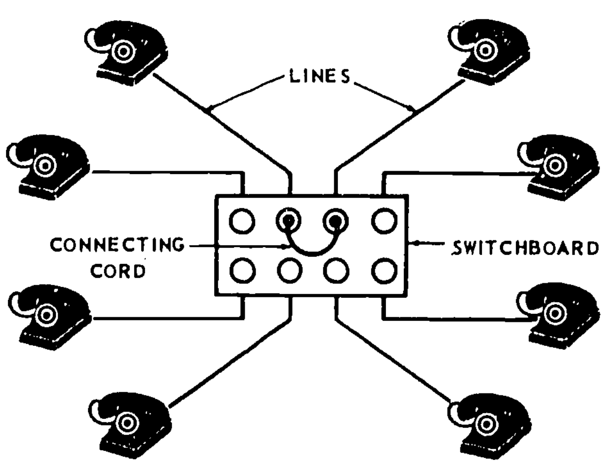
Figure 12-13.—Connections at terminal box.

Figure 12-14 shows how a switchboard simplifies connection between eight telephone stations. Each station is connected directly to the board. Connection between any pair of stations can be made at the board by means of a plug-fitted cord. Particular types of switchboard are discussed later in this chapter.

DISTRIBUTION FRAMES

When a large number of lines come into a switchboard, there must be some arrangement for rapidly connecting them to the proper jacks on the board. This is accomplished by the use of distribution frames. These frames not only provide for an orderly arrangement of incoming lines, but also serve as an effective means for identifying outside lines where they enter the central office. Main distribution frames (MDF), either in manual or in dial systems, serve these two purposes. They connect the inside equipment with outside lines, and they interconnect the various units of inside equipment. Figure 12-15, view A shows the vertical side of a combined distributing frame. Figure 12-15, view B shows the horizontal side.

Each outside line is connected to a PAIR of terminals on one side of the frame, as shown in figure 12-16. Notice how the corresponding terminals on the opposite side of the frame are connected to lines to the switchboard. For each line in use (that is, connected up in this fashion), jumpers or cross-connecting wires make a connection between terminals.



73.178
Figure 12-14.—How eight telephones can be connected by switchboard.

The side of the frame carrying the terminals to which outside wires are connected is usually known as the vertical side of the MDF. Cables or lines from the inside equipment terminate on what is usually called the horizontal side (in some installations, however, both sides are vertical). Cross connections between vertical and horizontal sides are made by jumpers.

The use of distribution frames permits rapid switching of the switchboard load. It also makes outside wires accessible without any disturbance of the switchboard wiring, and provides a convenient place from which to test for line faults.

Distribution frames may be either the wall frame or the floor frame type. Wall frames are used in small central offices, and consist of units capable of accommodating 20 pairs, or lines. Screw type terminals are frequently used, because they allow for easy disconnections. Jumpers are flexible and can be made fast to any set of terminals. Standard floor frames, also used at military installations, differ from wall frames in that they have one side vertical and one horizontal, while a wall frame has two vertical sides.

Besides being distinguished as wall or floor frames, distribution frames may be distinguished as type A or type B. The type A frame has the vertical side of the frame connected to the switchboard. The type B frame has the vertical side connected to outside lines.

SWITCHBOARD PROTECTIVE DEVICES

Because the distribution frame is the dividing point between the outside plant and the inside plant, it becomes the logical location for central office protective devices.

The switchboard must be protected against excessive voltage, including that caused by lightning; and against excessive current, including current surges through unexpected channels. The protective devices must operate before

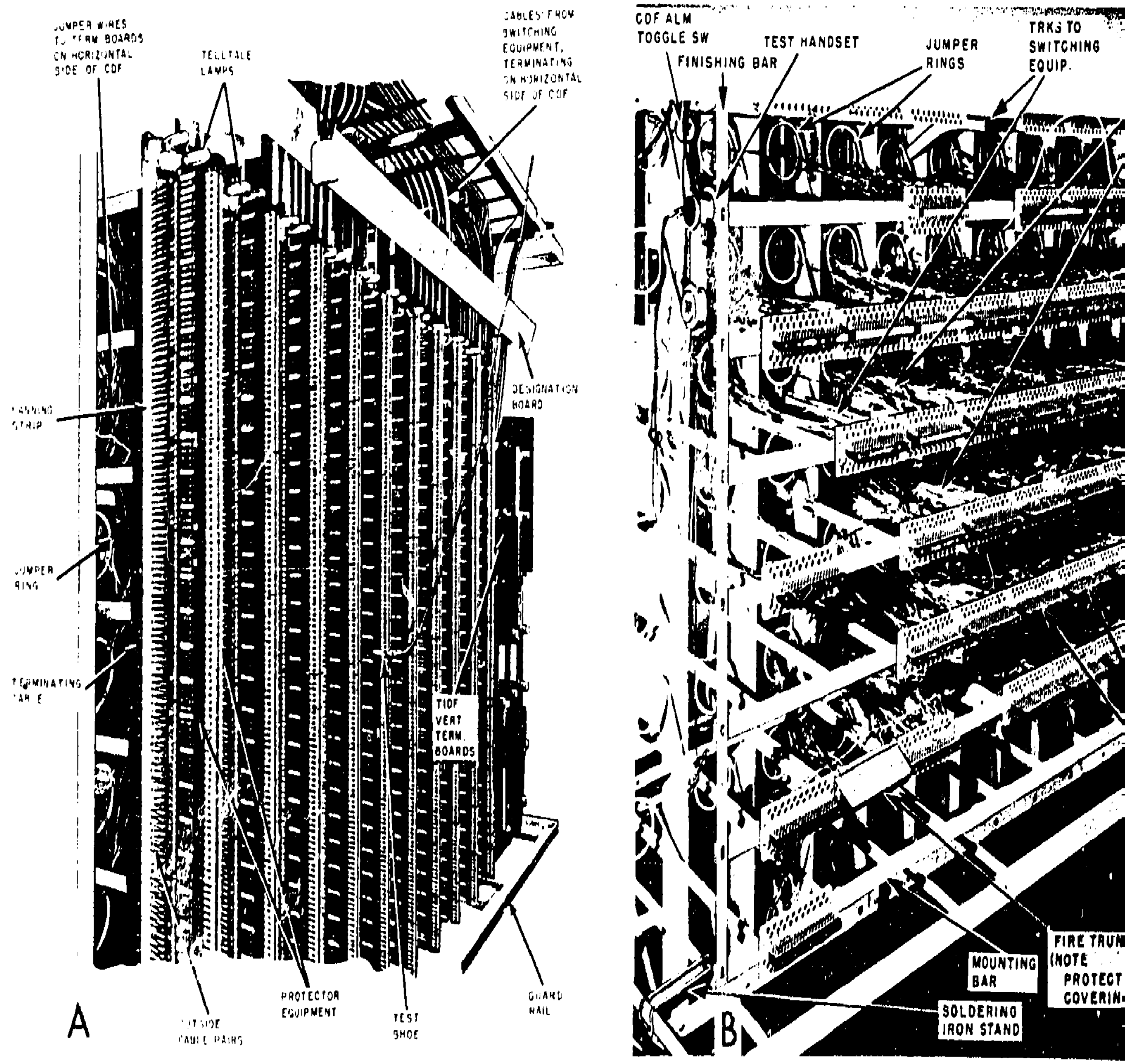
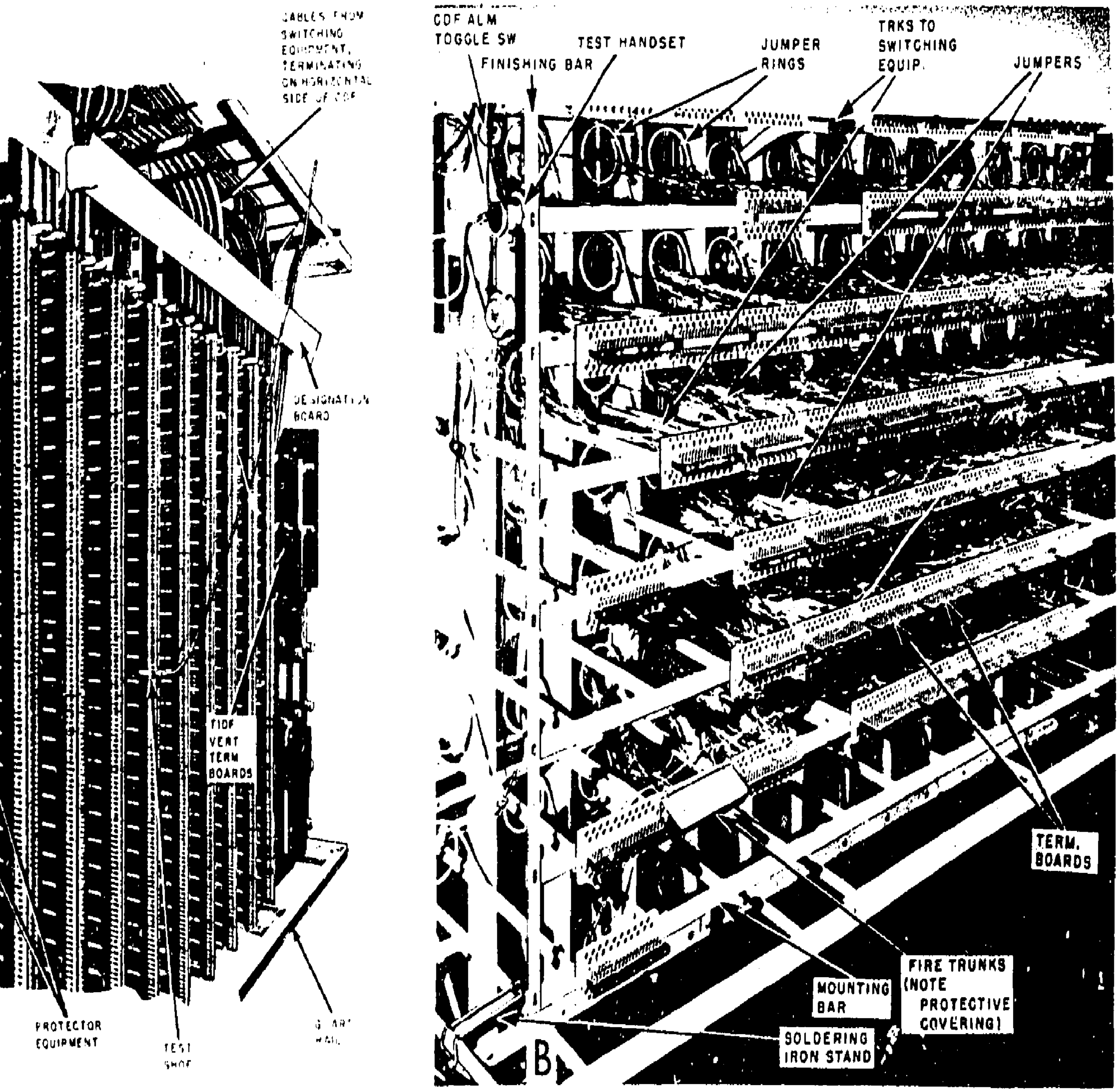


Figure 12-15.—(A) Combined distributing frame, vertical side (B) Distributing frame, horizontal side.



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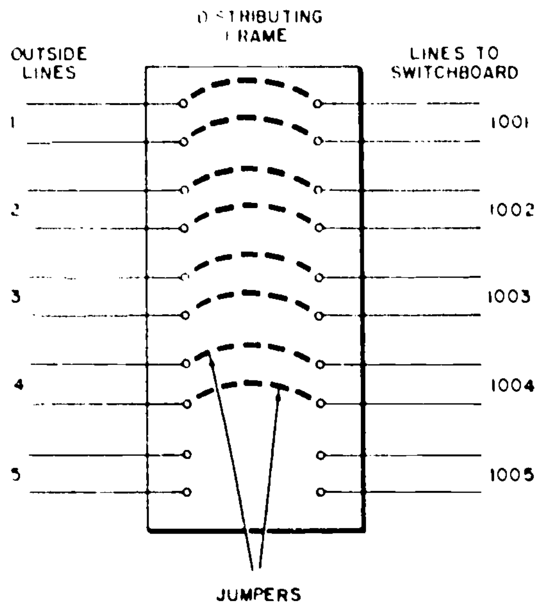
--(A) Combined distributing frame, vertical side (B) Distributing frame, horizontal side.



73.179(73G)
Figure 12-16.—Connections made through distribution frame.

damage occurs, but they must not be sensitive enough to interrupt service by functioning as a result of lesser types of artificial or natural disturbance.

Air gap arresters provide protection against excessive voltage. Protection against accidental current surges is required only if the excess flows for an appreciable interval; a heat coil is the best protective device here.

Fuses protect against excessive current other than instantaneous surges. In a large central office there may be hundreds of switchboard fuses, to protect the switchboard from its own battery current if the current flow is too high.

CIRCUITS

On a common battery switchboard there will be a telephone relay circuit, a common battery line circuit, common battery cord circuits, and the "operator's telephone circuit." These are described in the following paragraphs.

Relay Circuits

The relay is a control device which provides for automatic signaling on the common battery system. A relay is, in effect, an electrically operated switch which makes it possible to control (by means of one switchboard circuit) the operation of one or several circuits on other switchboards. There are many different types of relays, as far as construction goes, but the principle of operation is the same for all.

Essential parts of a relay are: armature, windings, core, and springs. It is the motion of the armature that opens or closes the controlled circuit. Windings provide the path for current flow. The number and types of winding depend upon the particular function of the relay. The core is the magnetic material. The contact springs are of silver or silver alloy, and operate either normally open or closed. The number and arrangement of contact springs depend on the strength of the magnetic field, which in turn depends upon the number of turns and the value of current in the windings.

Relays are provided with covers, to keep out dirt and to protect against mechanical injury. Some have a small setscrew, called a residual screw, which can be adjusted to overcome residual magnetism in the armature.

Common Battery Line Circuits

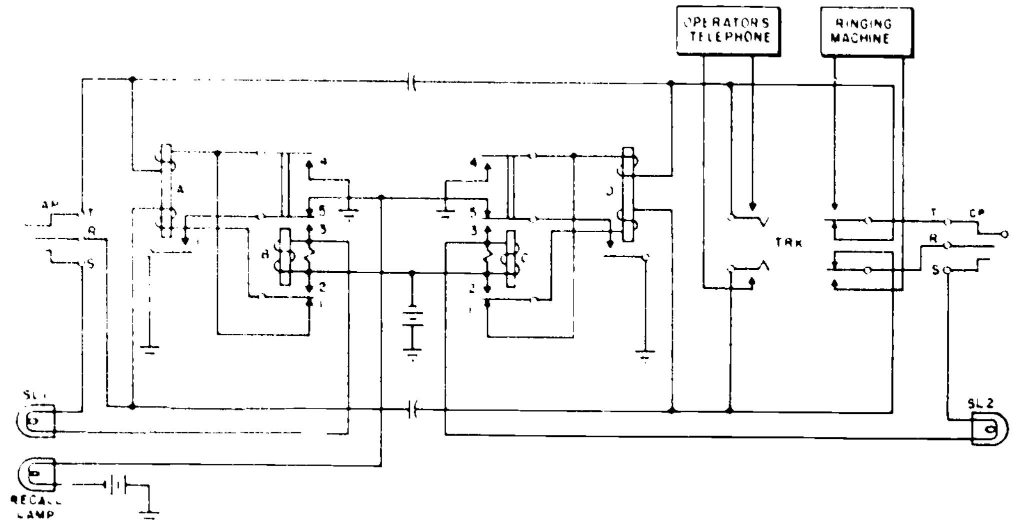
Common battery line circuits are of three types, as follows:

1. Series lamp line circuit, with a lamp connected through the auxiliary contacts of a cutoff jack.
2. Series relay line circuit, in which a relay is included, in addition to a lamp and cutoff jacks.
3. Cutoff relay line circuit, in which a cutoff relay is substituted for the auxiliary contacts of a cutoff jack.

Cord Circuits

Cord circuits prevent the branch containing the common battery from shorting out the receiver of the listening station. A retardation-coil cord circuit uses a relay to provide automatic supervisory signals. A repeating-coil cord circuit uses separate relays (supervisory relays) for this purpose.

A third type of cord circuit, called a universal cord circuit, is often used on military switchboards that serve both common battery and local battery stations. Such a circuit is shown in figure 12-17. It supplies battery voltage to the common battery lines, but not to the local battery lines.



73.180

Figure 12-17.—Universal cord circuit.

This circuit is called universal because it provides a talking circuit in either direction between two common battery lines, or between two local battery lines, or between one common battery line and one local battery line.

The various cord circuits provide for ELECTRICAL paths between selected stations, but they are not sufficient of themselves to enable the user of a calling telephone to tell the switchboard operator what station he wishes to call. For this, it is necessary that the operator be able to listen to or talk into each telephone. This need is met by installing an operator's telephone circuit for the entire switchboard.

Operator's Telephone Circuit

The function of this circuit is to connect the operator's telephone set across the line from any calling station, either before or after the called station is connected. The operator's telephone circuit, therefore, provides an additional voice frequency path which is in parallel with the cord circuit.

Generally, the operator's set is connected to the switchboard by means of a plug and jack. A lever switch allows the operator to cut his telephone into or out of any cord circuit. It differs from user's set in having no ringer and no hook switch contacts. Switchboards signal drops or lamps perform the function of the ringer. Operator's jack, plug, and lever switch substitute for the hook switch.

RINGING MACHINES

A ringing machine is a device that operates from a standard power source to provide ringing current for the switchboard and connectors. A variety of devices are available to meet different requirements. In any case they convert the a-c or d-c voltage of the power source to the required frequency (usually 20 hertz) of the ringing current.

If the power input is from a battery, a d-c vibrating reed CONVERTER changes the d-c to 20 hertz.

An a-c vibrating reed INTERRUPTER produces 20-hertz ringing current output from a 110-volt 60-hertz input. This is accomplished by alternately opening and closing the output circuit at regular intervals. The interruption of the output circuit results in an output voltage consisting of alternate positive and negative half-cycles which, over a 1-second period, are the equivalent of a 20-hertz frequency variation.

The machines described above have moving parts which need frequent adjustment and are difficult to maintain. Subcycle static frequency converters have been designed to minimize maintenance and replacement of parts. This device is essentially a series L-C circuit designed to resonate at 20 hertz. A switching action, accomplished electrically by a saturable reactor, allows the 60-hertz current to turn off and on at the proper times to develop the 20-hertz current.

SWITCH KEY

The switch key on the switchboard is simply a make-and-break spring switch. When you move the key handle, it causes a cam to press against the spring of the switch, and to open or close the contacts in the cord circuit.

When the switchboard operator receives an incoming call, he pushes the key forward into the talking position. When he has made the connection with the circuit on which the call is to be placed, he pulls the key back into ringing position. When the calling party has a connection with the called party, the operator lets the key return to neutral position. There is now a closed circuit from calling to answering plug. This circuit is broken when one of the telephones is returned to its cradle.

INSTALLING A TELEPHONE

After you have strung the outside lines, installed the switchboard, and provided for the necessary connections between main lines and subsets, then a telephone can be installed. The steps for installing a telephone will be briefly outlined here, then explained at more length in subsequent section.

Span the drop wire from the pole to the building, and train it along the building to the entrance hole. Bring it through the hole, and connect it to the INPUT side of the fuse, lightning arrester, or other protective device.

Connect the inside wiring to the OUTPUT side of the protector; run the inside wiring to the subset location; and terminate the inside wiring at the connecting block.

Attach the subset wires to the connecting block; secure the drop wire to the pole; tap it to the designated pair of wires in the main run (through the terminal box if cable is used; directly to a pair of open wires if the main run consists of open wires strung on crossarms); and finally check the installation.

WIRING

The drop wire is exposed to the weather, and both wind and rain can do damage unless the wire has been given proper protection. Both conductors should be insulated with a rubber compound, and the wire should then be further protected with a covering of weatherproof cotton braid. The wire used inside a building is rubber insulated, but protective braid covering is not necessary, except in very damp locations.

Drop wire may be either the twisted-pair type or the parallel-drop type. The twisted pair consists of two conductors separately covered but spiraled together. In a parallel-drop wire there are two separately insulated wires that run parallel to each other and are under a single braid covering.

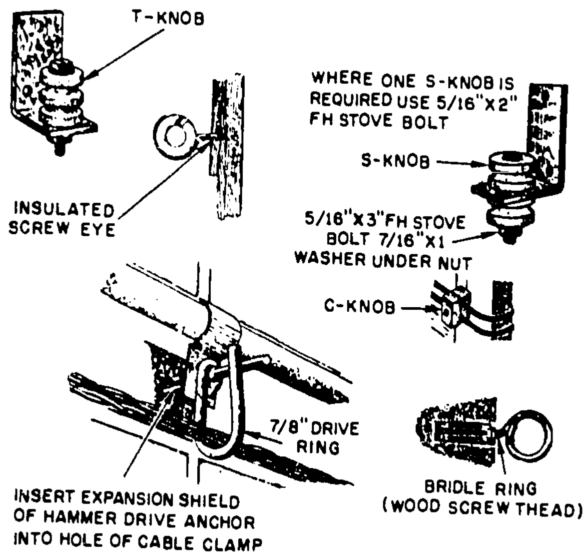
The drop wire must have a definite sag between pole and building, but the weight of the wire should not be allowed to exert a strain on the remainder of the run. Clamping the drop wire prevents this.

The clamp installation consists of a wedge secured to a copper wire loop, and a tapering sleeve. The copper wire loop is attached to the support point on the pole. Then the sleeve is placed over the drop wire, with the tapered end toward the support point, and pushed firmly up on the wedge. When the free end of the drop wire is attached to the building, the weight of the span induces a tight fit at the wedge.

The type of support you use to train the drop wire along the building depends on the material of the building wall. On wood or other combustible material, supports must be insulated. Anchor bolts are used on concrete and masonry walls. Toggle bolts are used on clay tile walls. Some commonly used types of supports on various kinds of walls are shown in figure 12-18.

Wire can be run on a sheet-metal wall (such as the wall of a quonset hut) without the necessity for drilling into the metal. Nail knobs (similar to the T-knob shown in fig. 12-18, but with a nail instead of a bolt) can be driven into points where the sheet metal is secured to the rib-frames. On a metal base the knobs must, of course, be insulated.

On a frame building you can attach the drop wire with an S-knob (fig. 12-18) and a drop wire



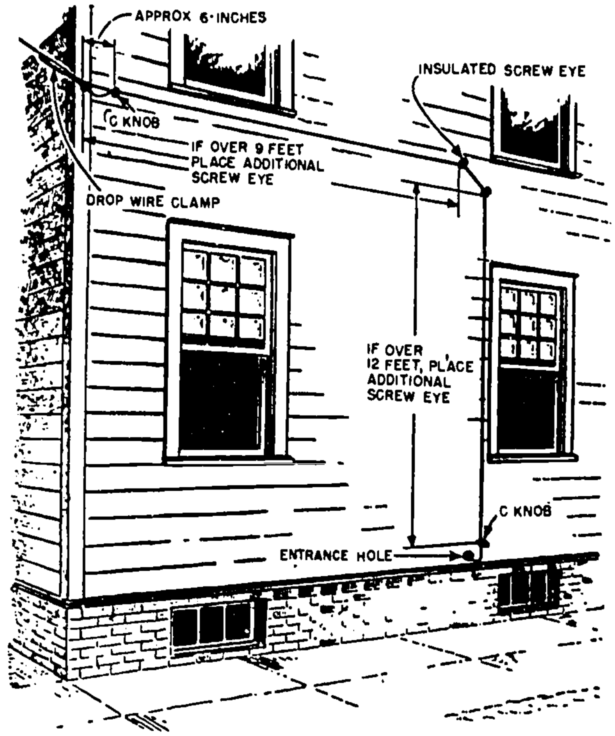
73.181
Figure 12-18.—Supports for telephone wires.

clamp. In a line with the S-knob, and about 6 in. away, screw in a C-knob (fig. 12-18). Still following a horizontal line, attach an insulated screw eye (fig. 12-18) a few feet further along. The horizontal distance will depend on the location of the entrance hole, because you want the wire to drop from a point vertically above the hole. Screw in another insulated screw eye and another C-knob as shown in figure 12-19, if the indicated distances exist.

Figure 12-19 will aid you in installing a drop wire. You attach the drop wire clamp to the drop wire and attach the clamp to the S knob. Allow a slack loop of about 12 inches (6 inches for slack and 6 inches to the first C knob). Place the drop wire in the C knob. Tighten it down and run it through the necessary insulated screw eyes to the last C knob. Allow a 4- to 6-inch drip loop between the last C knob and the entrance hole. A plastic or porcelain tube is usually inserted in the hole to protect the entering wire. Where a protector is used, the DROP LOOP ends in the protector, and the inside wiring goes through the tube.

CONNECTIONS TO PROTECTORS

The wire from pole to building usually crosses light and powerlines, and is always exposed to the possibility of being struck by lightning, It therefore requires some protective device, such as a fuse or lightning arrester. This protector may be enclosed in a weather-proof metal can outside, or it may be an inside unit mounted on a porcelain block.



73.182
Figure 12-19.—Drop wire installation on wood frame building.

Fuses are inserted in series with the line, but an arrester is placed between line and ground. With a fuse, current must pass through the fuse before it can reach the output terminals to which the subsets are connected. An arrester ensures that excessively high potential is bypassed to ground before it can reach the output terminals.

When you bring in the drop wire, remove the insulation for about 3/8 in. from the end, and then bring the bare ends of the conductors around the input terminal posts on the protector. Give each wire a 3/4 clockwise turn around its post, and then tighten the terminal nuts.

Connect the inside wiring to the output terminals—that is, to the outside binding posts on the bottom of the protector.

The center terminal is the ground terminal for the arrester. Connect it, by a single insulated conductor, to a cold water pipe, if possible. If there is no available metallic object in close contact with the ground, drive a ground rod. NEVER ground to gas pipe systems or to lightning rods. Hot water, steam, or sprinkler pipes provide poor grounding, and electric railways should never be used to ground any equipment other than that supplied by the railway's own circuit.

CONNECTIONS TO SUBSETS

In routing the inside wiring from protectors to subset locations, keep the run parallel with or at right angles to the building walls. Wherever wires must pass around sharp corners or over metal objects, use friction tape to protect them from mechanical injury. If you must run wiring along a floor or ceiling, place it in a metal raceway for protection. You can secure inside wiring to walls and ceilings with insulated staples, because inside wiring carries a protected low voltage.

At the telephone location, run the inside wire to the connecting block. One of these blocks usually consists of four terminal posts mounted on a composition base and provided with a removable cover.

Bring the inside wire to the back of the connecting block, wind it around the projecting lugs, and connect it to the terminal posts on the face of the block. There will be less strain on the wire than if the connection were made directly, and there will also be enough wire so that it can be reconnected if a bare end breaks off.

These connecting blocks provide not only a point at which to connect inside wire and telephone cord, but also a convenient test point.

CONNECTIONS TO THE MAIN RUN

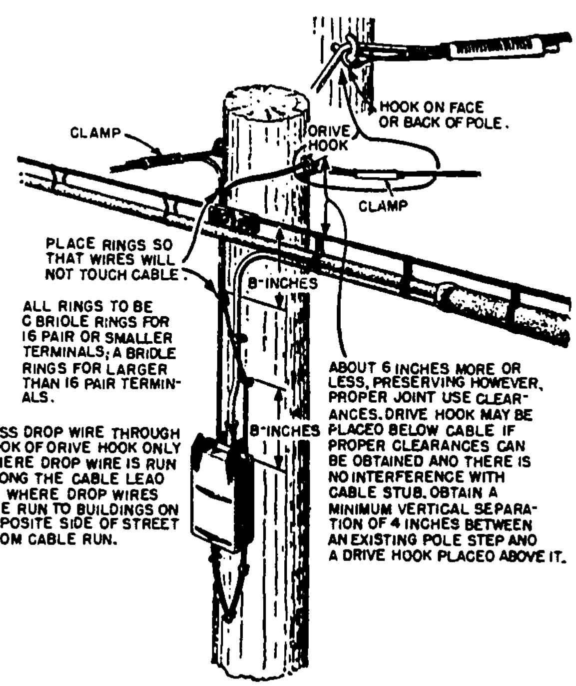
Before you can make final connections with the main run, there is the matter of training the drop wire back to the connecting point in the run. The method to follow in doing this will depend upon whether the drop wire is to be connected to open wires or to a terminal box.

If the drop wire is to be connected to open wires, train it under the crossarm to the point of connection. Use bridle rings to support the drop wire along the crossarm. The type of bridle ring you will use has an open spiral eye through which you can slip the wire after the ring has been screwed into the crossarm.

Each conductor of the drop wire should be separate, as if for splicing. You can then wrap each of the two conductors around the main run wires, for about three turns, before extending the conductors to the point of connection. The crew chief will tell you which pair of wires to use in the main run.

The joint at the connection is solderless. The connector will probably have a slotted bolt, nut, and washer assembly. Place the main wire in the slot, and wind the bared conductor of the drop wire around the bolt, between two washers. Be sure to wind in the same direction in which the nut tightens. Turning down the nut will ensure a firm joint.

Terminal boxes were previously described. The method of connecting a drop wire to a terminal box is illustrated in figure 12-20. Important matters to bear in mind are: connect the pairs of binding posts to the proper wires in the main cable; remove only a small amount of



73.183

Figure 12-20.—Connecting drop wire to a terminal box.

insulation from the drop wire, so there will be no risk of a bare conductor touching an adjacent post; make one conductor of the drop wire slightly shorter than the other, to accommodate the post positions; and make sure the conductors are wound around the posts in the same direction as that in which the nuts tighten.

At the pole, you will have to attach the tracer conductor of the drop wire to the ring line, and the plain conductor to the tip line. The tracer conductor must always be connected to the RIGHT-SIDE binding post, to ensure that the connections are made correctly. This is also standard procedure in making connections at the protectors and at the connecting blocks; that is, always connect the gracer wire to the right-hand terminals.

At the central office the positive side of the battery is permanently grounded. This makes the negative or tracer wire a hot wire, and it must therefore be readily identifiable at all points for purposes of testing and repair. In a twisted-pair drop wire the outer covering often has a raised thread to identify the tracer wire. In parallel-drop wire the conductor with the ridged insulation is the tracer wire. In the inside wiring the wire with a red thread is the tracer.

HOOKING UP A HANDSET

A telephone set is practically a self-contained unit. In a desk or table set, the base contains ringer, induction coil, condensers, and hook switch. The transmitter and receiver are contained in the handset. Installing the set simply involves connecting the terminal lugs of the telephone cord to the block.

CHECKING AN INSTALLATION

As soon as a telephone is hooked up, check to ensure that connection to the proper line has been made. Then have someone ring back from the switchboard, to check the bell circuit. Check for satisfactory strength and quality of voice transmission.

BELLS AND BUZZERS

Where there are several telephones at a station, all working from one or two incoming lines, bells and buzzers will be a great convenience. To energize a bell circuit, you will need a low-voltage source—either dry cells or a bell transformer connected to a lighting circuit. You will require a pushbutton to make and break the bell circuit, a signaling device, and a wire to connect these components.

Mount a bell at each telephone. There should be a pushbutton for each bell, but these buttons should be located together at the central telephone location. Connect the transformer to the lighting circuit at any convenient point.

Use No. 18 wire for the bell circuit. This wire is attached to the secondary side of the transformer. One conductor is trained directly over to the bell; the other connects with the pushbutton. Another wire runs from bell to pushbutton, being connected at the screw terminals of each of these components.

FIELD TELEPHONE SYSTEMS

A field set is a telephone system designed for easy transportation from one location to another, and for rapid installation. Navy field set components include central office sets, distribution systems, and station equipment, capable of serving small, medium, or large bases. Because the SEABEES use a considerable amount of Army equipment, brief descriptions will be given of some of the commonly used Army field sets you may need to install and operate.

TC-2 SET

The TC-2 set is a central office set with the receivers mounted in the headband. It consists of a combination of local and common batteries, switchboard, main distributing frame, power unit, power panel, rectifier, and accessories. The switchboard has 57 circuit lines and 3 trunklines for connections to other switchboards.

The power unit is a self-contained 2500-watt a-c generating set, driven by a gasoline engine, and producing 120-volt single-phase 60-hertz current. The panel contains a voltmeter and ammeter for use in controlling the rate of charge of the storage batteries. A rectifier capable of charging the batteries at a maximum rate of 12 amperes is installed to change the alternating current to direct current.

The components of this set can be easily damaged, and care must therefore be exercised in unpacking. When installing, locate the switchboard as far away as possible from any source of excessive noise.

Figure 12-21 shows an interconnecting diagram of a TC-2 set. Cords may be small, flexible insulated cables or stranded wires.

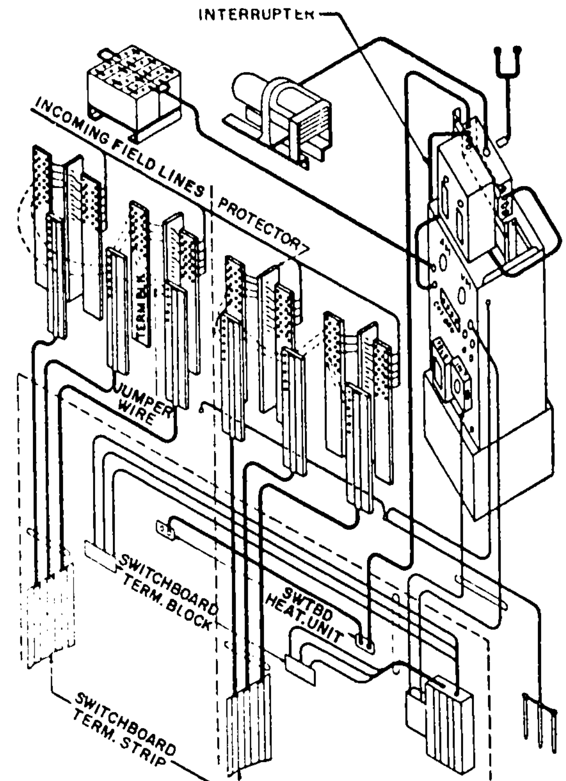


Figure 12-21.—Interconnecting diagram of a TC-2 central office set. 26.118

MANUAL TELEPHONE CENTRAL OFFICE AN/TTC-7A

The AN/TTC-7A is a transportable telephone central office (central office set) which basically can handle 200 local lines, 20 plug supervision trunks, and 20 manual or dial trunks. If the set is used to terminate incoming manual dial or trunks from another AN/TTC-7A, 20 of the line circuits must be used for termination. When not being used as terminators, the line circuits can be set up for either 200 common battery (CB) lines or 100 CB lines and any combination of 100 local battery (LB) and CB lines.

The basic AN/TTC-7A installation can be modified to handle up to 960 lines, 100 plug supervision trunks and 100 manual or dial trunks by the installation of additional components.

The main components of the AN/TTC-7A are shown in figure 12-22. The location of the units is limited only by the length of the interconnecting cables (these come in set lengths) and the amount of space in which the set is to be installed.

FIELD SWITCHBOARD SB-22A/PT

The SB-22A/PT is a lightweight field type, local-battery switchboard. Figure 12-23 names the main parts. The set is a self-contained unit, and requires no special mounting equipment for operation.

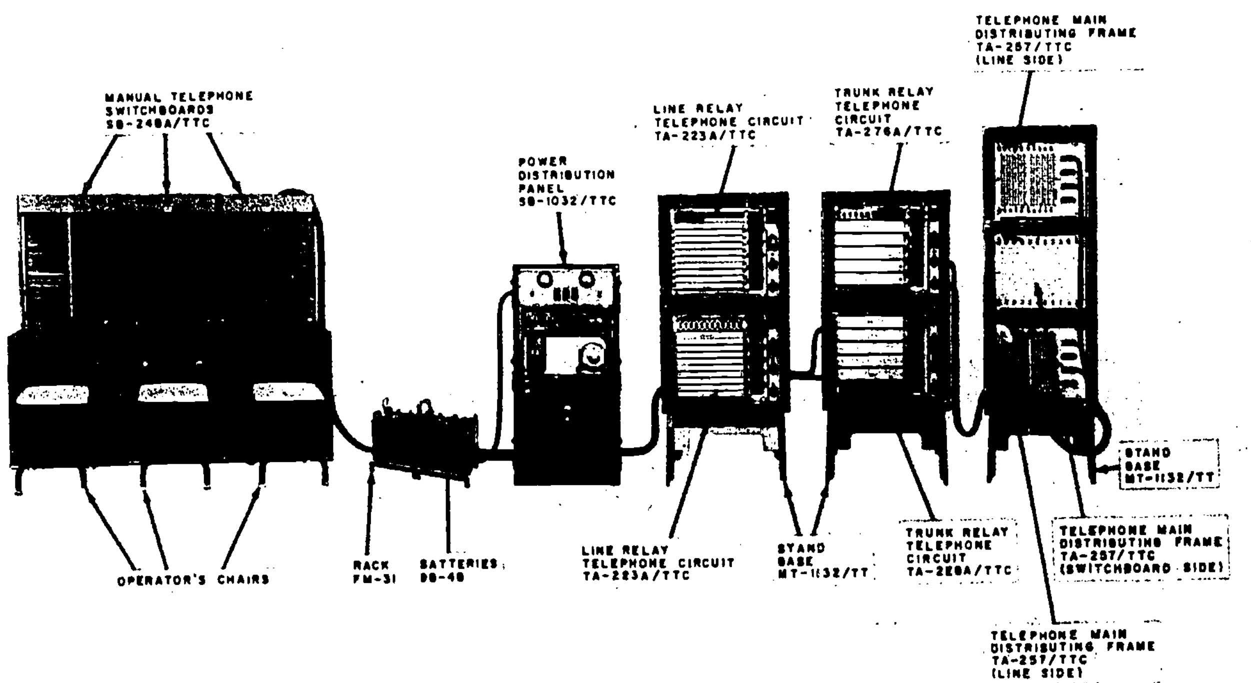
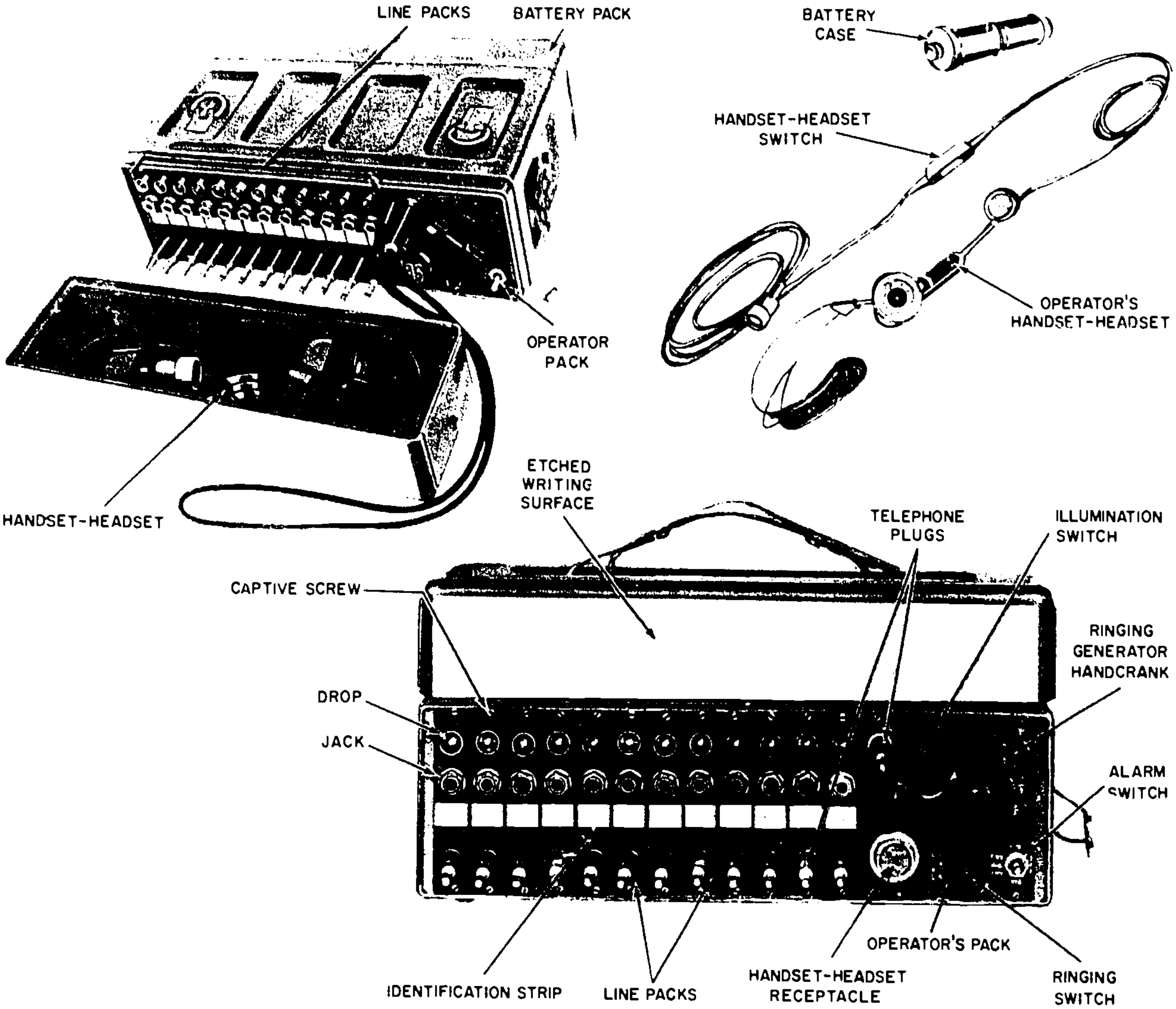


Figure 12-22.—Manual telephone central office AN/TTC-7A, main components. 26.268



26.104

Figure 12-23.— SB-22A/PT manual telephone switchboard.

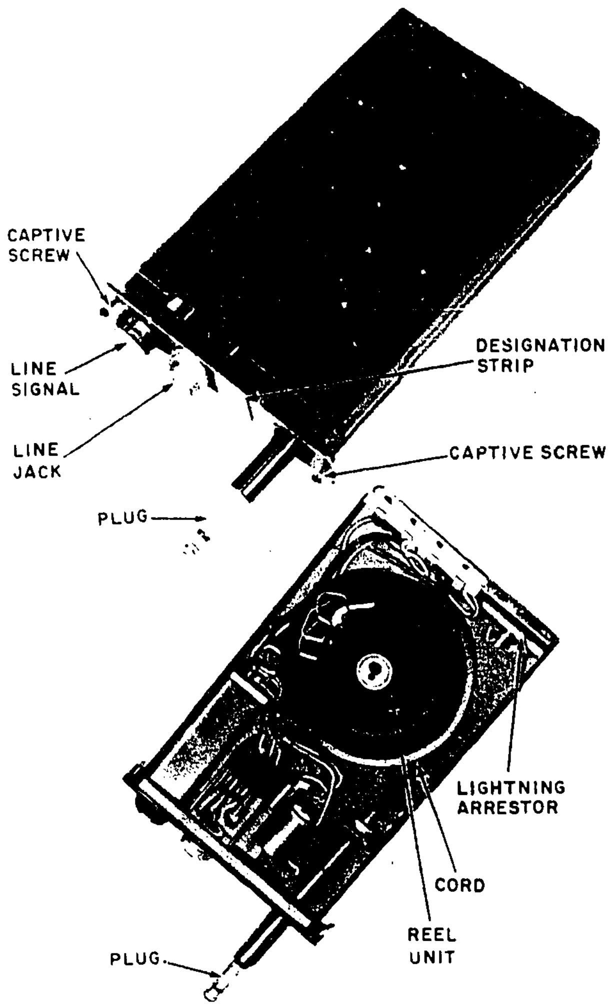
The switchboard is comprised of four major components. Three components make up the actual switchboard (the line pack, operator pack, and battery pack). The other component is the handset-headset.

The switchboard is designed to establish a working telephone system for units up to and including battalion size. The SB-22A/PT can be used for interconnection up to twelve local-battery lines and for remote control radio [illegible]munications. It may also be [illegible] a common-battery (CB) switch[illegible]

Under normal conditions, you will be concerned with only the telephone lines. The procedure for connecting the wires of the switchboard to a radio circuit is very similar to the procedure for making connections to the telephone circuit.

Line Packs

The 12 line packs are located on the left side of the front panel. A line pack is shown in figure 12-24. Each line pack is fastened to the switchboard by two captive screws, one at the



26.105

Figure 12-24.—Line pack.

top of the unit, and the other at the bottom. The line pack contains a reel unit, a line signal, a jack, an identification strip, and a lightning arrestor.

The REEL UNIT consists of a reel, a cord, and a plug. The cord is fastened to the spring-loaded reel by three screws at one end and is equipped with a standard switchboard plug at the other end. The cord may be extended to a maximum distance of 35 inches and is retracted by the spring-loaded reel.

The LINE SIGNAL consists of a plastic ball (indicator) with a permanent magnet embedded in it. The black plastic ball has a white strip around it. The magnet is embedded in part of this strip (fig. 12-25). When a telephone user turns the crank of the hand generator serving the telephone, a circuit is completed, setting up a magnetic field in the armature of the line signal indicator which attracts the magnet. The magnet aligns itself with the core, and the indicator shows white. When the line signal shows white and the operator inserts the operator's cord plug into the associated line jack, the ball is mechanically restored to show black.

The JACK is used in conjunction with the cord of the operator's pack, or with cords of the line pack, to interconnect line circuits.

The IDENTIFICATION STRIP is a piece of white plastic fastened beneath the line jack. Marks on this strip identify the telephone circuit associated with the line pack.

A LIGHTNING ARRESTOR is provided for protection of the line from outside voltages.

Operator's Pack

The operator's pack (fig. 12-26) is located on the right of the front panel. The pack consists of a reel unit, ringing equipment, alarm equipment, and a handset-headset receptacle.

The REEL UNIT is identical to that of the line pack. The ringing equipment consists of a

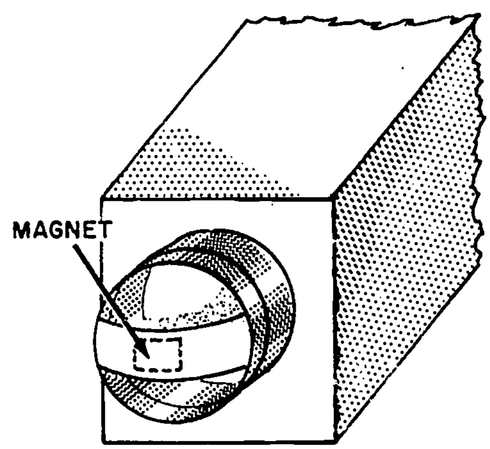


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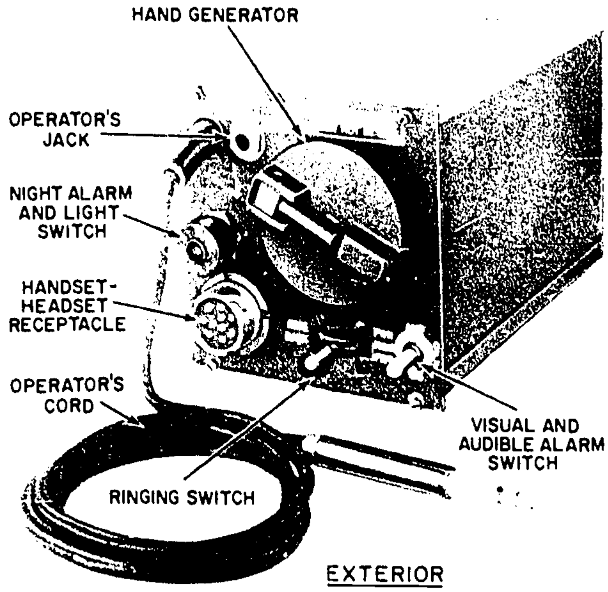
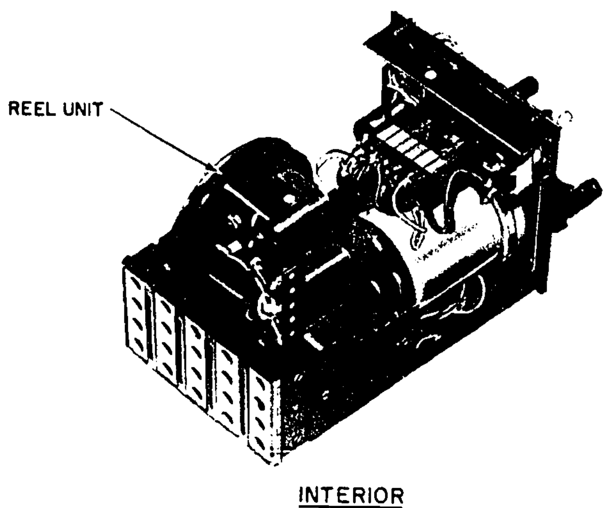
Figure 12-25.—Line signal indicator (with indicator lens removed).





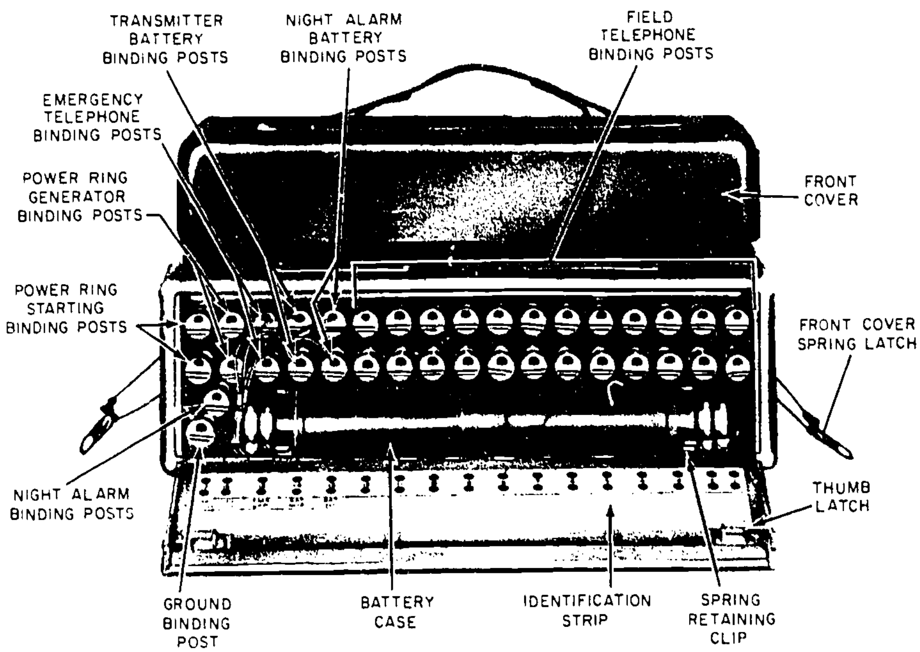
26.106

Figure 12-26.—Operator's pack.

hand generator and a control switch. Ringing current is generated when the handcrank is rotated. The control switch has two positions: RING BACK and PWR RING FWD. This switch enables the operator to connect ringing current to the calling or to the called telephone.

The ALARM EQUIPMENT provides a more positive signal for the operator than that afforded by the drop mechanism of the line pack. The alarm equipment consists of the signaling buzzer and a lamp. When the switchboard is signaled by an outlying telephone, the drop on the line pack associated with the outlying field telephone falls; this completes a circuit through the alarm lamp or the buzzer. Depending on the setting of the switch, either the lamp lights or the buzzer sounds.

The HANDSET-HEADSET receptacle is a polarized, bayonet-locking, 10-conductor receptacle



26.104.2

Figure 12-27.—Rear view of switchboard, SB-22A/PT.

which is used with the plug on the handset-headset cord.

Battery Pack

The battery pack is located under the rear cover of the switchboard (fig. 12-27). It holds four BA-30 batteries which supply power to operate the set.

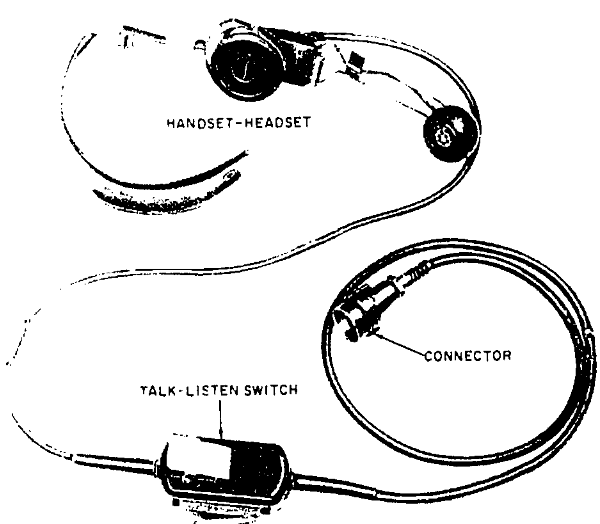
Handset-Headset

As illustrated in figure 12-28, the handset-headset consists of the actual handset-headset, the talk-listen switch, and the 10-conductor plug for connection to the operator's pack.

Unpacking

You should instruct your crew to be careful in unpacking the equipment. Immediately upon unpacking, you should have it inspected for possible damage during shipment.

The original packing cases and containers should be saved, so that they can be used again



26.104.3

Figure 12-28.—Handset-headset.

when the equipment is repacked for storage or shipment.

Connecting Procedures

The ground connection should be made before connecting the wire lines to the switchboard. Select the lowest, dampest site in the vicinity; clay or loamy soil is best. Scoop out a hole 6 inches deep and drive a ground rod into the hole until the top of the rod is about 3 inches below the undisturbed ground surface. Connect one end of the wire to the ground rod. The earth around the rod should be saturated with water, and the hole filled with earth. Now connect the other end of the wire to the ground binding post (fig. 12-27) located on the frame behind the rear access door.

To connect the wire lines to the switchboard, a pair of binding posts should be selected and connected to the desired circuit. Be sure to record the circuit identification on the proper identification strip.

When the wire lines are connected, you are ready to install the four dry cell batteries. Remove the battery case and insert two batteries into the compartment so that the brass contact end of each battery faces outward. Repeat the procedure for the compartment at the other end of the battery case. After completing this operation, replace the case into the spring retaining clips.

After the connections are made, talk over the line and note the quality of transmission. If transmission is poor or speech cannot be heard at normal speech level, check the connection wiring. If the trouble continues, replace the operator's pack and check again.

Stacking of Two Switchboards

To serve more than 12 but fewer than 30 lines, stack the 12-line switchboards. Remove the operator's pack from the switchboard and install five line packs in the empty space. This modified switchboard should be placed on top of a normally equipped switchboard. Use two jumpers to connect the two switchboards. One jumper must be connected to the NA binding posts of both switchboards, and the other jumper must be connected to the GND binding posts of both switchboards. Be sure that the jumpers pass through the slot at the side of each switchboard. Only one set of batteries is required to serve both switchboards; the battery case from the one containing the 17 line packs (from which the operator's pack has been removed) should be removed. The field telephones can then be connected. A maximum of 29 lines can be served with this arrangement as shown in figure 12-29.

Maintenance and Repair

See that your crew makes frequent inspections of the equipment to keep it in good working order. Dust, dirt, grease, or moisture should not be allowed on the exterior of the switchboard or the handset-headset. A clean, dry, lint-free cloth or a dry brush should be used for cleaning. The electrical contacts on the frame of the switchboard should be cleaned with a cloth moistened with drycleaning solvent, and should be wiped dry with a clean dry cloth. A burnishing tool should be used to clean the switch contacts.

Rust, fungus, dirt, and moisture tend to accumulate on the binding posts, plugs, and external portions of the line jacks. Have these removed with a dry rag or brush. The battery case and clip contacts should be inspected for corrosion, moisture, fungus, and tightness. All lines should be checked for kinks, strains, moisture, fungus, and loose terminals; also have the insulation checked to see that it is not frayed, cut, or otherwise damaged.

Normally moving parts of the SB-22A/PT do not require lubrication. When necessary, lubricate the spring latches of the front cover, and the thumb latches and hinge of the rear access door.

Failure of the switchboard to operate properly is usually caused by one or more of the following:

1. Rundown batteries
2. Defective operator's handset-headset
3. Defective line pack
4. Defective operator's pack

Rundown batteries may be indicated by any of these difficulties:

1. Pull switch is pulled out, but lamp fails to light.
2. Drop of a line pack indicated that a telephone is signaling the switchboard, but the lamp or buzzer of the operator's alarm fails to work.
3. The operator cannot talk to any of the telephone users.

Remove rundown batteries, and replace them in the manner previously described.

A defective handset-headset prevents the operator from talking to any of the telephone users, from receiving calls from any of the

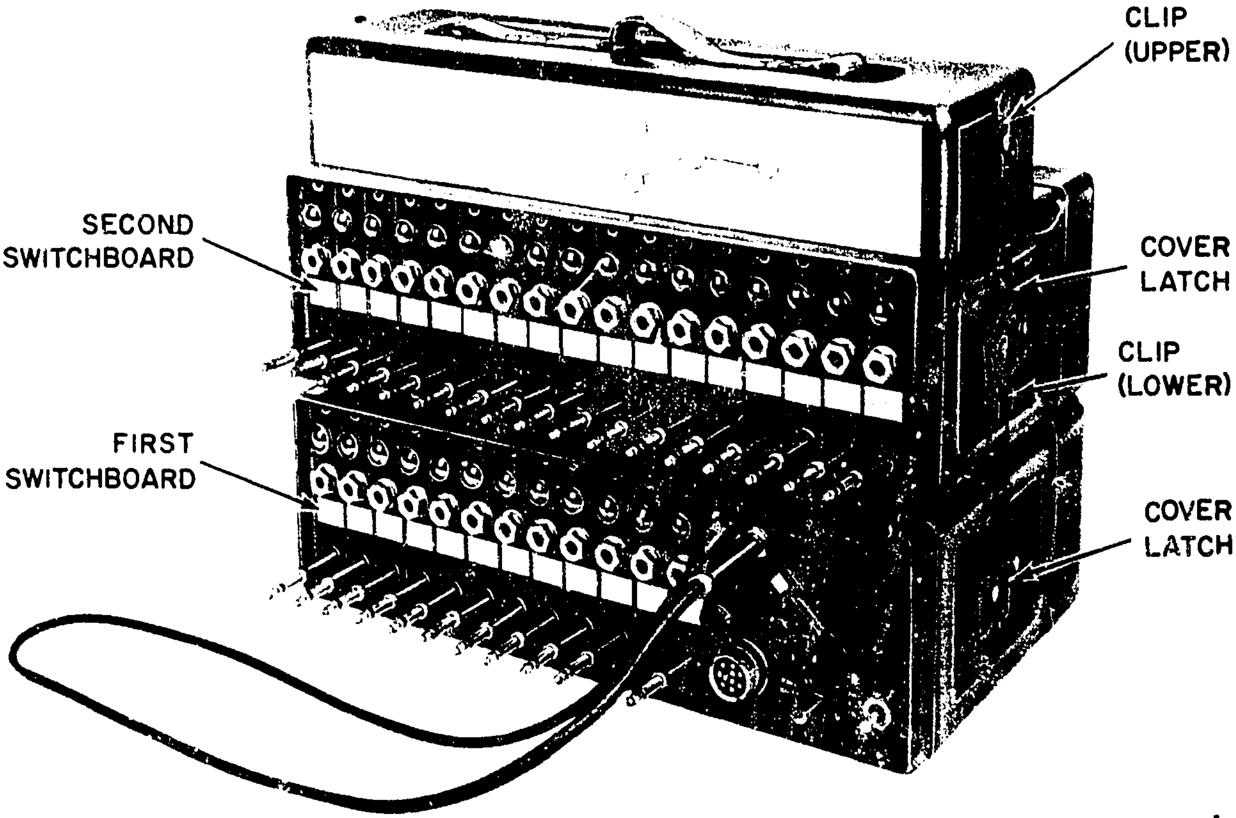


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Figure 12-29.—Installation arrangement for two switchboards.

outlying phones, or both. Replace defective handset with one that is in working order.

A defective line pack may be indicated by any of the following troubles:

1. The user of a telephone cannot signal the operator because the drop does not function.
2. The drop of a line pack for a particular telephone works, but the operator's alarm fails to function. (If this difficulty occurs with all telephones, the trouble may be rundown batteries or a defective operator's pack.)
3. The operator cannot talk to or receive calls from the user of a telephone.
4. The users of two telephones cannot converse with each other, but the operator can converse with each user separately.

The line pack is a self-contained, plug-in unit. It may be removed by loosening the two captive screws from the front panel, inserting the plug into the jack, and pulling on the plug until the line pack is free from the front panel. The replacement should then be inserted. After the two captive screws are tightened, the new line pack is ready for operation.

A defective operator's pack may be indicated by any of the following difficulties:

1. Lamp fails to light when a pull switch is pulled out (also may be caused by burned-out lamp or rundown batteries).
2. The operator's alarm fails to work when the drop of a line pack indicates that a telephone is signaling the switchboard (may also be caused by rundown batteries).
3. The operator cannot ring any field telephone.
4. The operator cannot talk to any telephone users (may also be caused by a defective handset-headset or rundown batteries).

5. The operator cannot receive calls from telephones on the line (may also be caused by a defective handset-headset).

6. The operator cannot ring back.

The operator's pack is also a self-contained plug-in unit. A replacement is ready for operation after installation of the unit and tightening of the four captive screws.

If at all possible, you should always have handy a circuit wiring diagram and exploded views of the various parts of the SB22A/PT switchboard, in order to make emergency repairs.

FIELD TELEPHONE TA-312/PT

The TA-312/PT field telephone (fig. 12-30) is a versatile phone for use in manually operated two-wire CB or LB field systems. It can be used either outdoors (regardless of weather conditions) or inside as a desk or wall phone. Besides being used as a phone it can control remote control radio equipment.

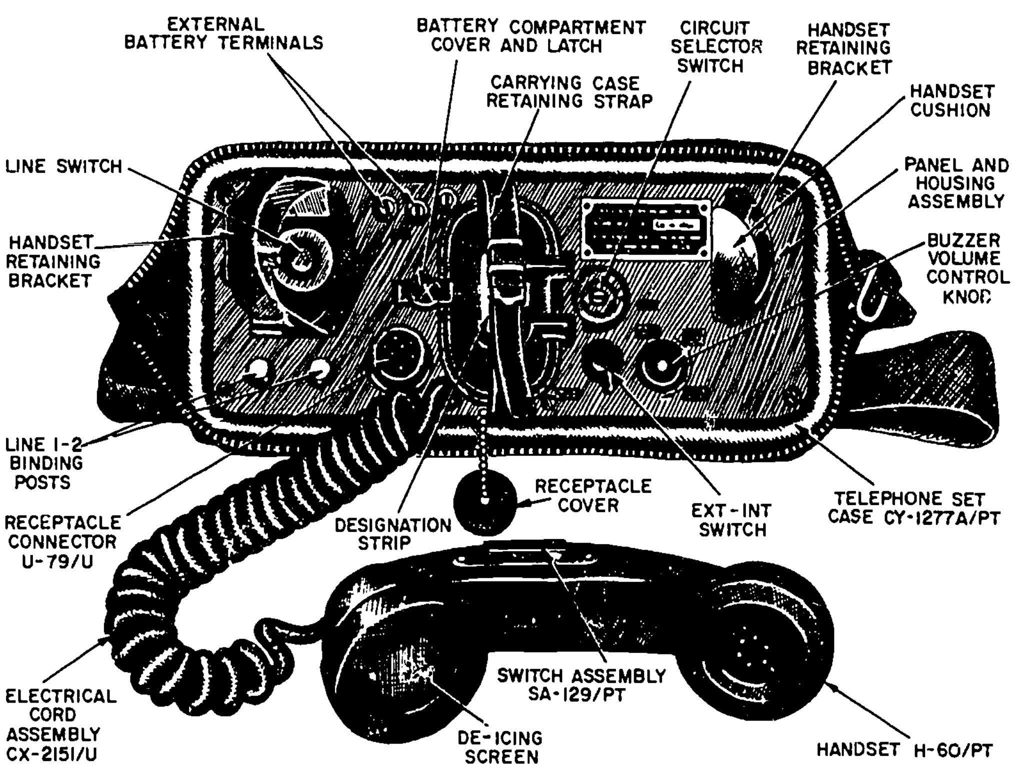
Functions

The unit is self-contained, requiring two internal batteries or an external 3-volt a-c source (which is connected to the external battery terminals) for operation.

The set is designed to allow the handset to hang in the housing panel (handset retaining bracket) when not in use. When the handset is in the retaining bracket, the line switch disconnects the internal battery. A receptacle connector is provided for use of an external handset/headset (fig. 12-28). The EXT-INT switch determines which handset is used.

The phone can be used in three modes as selected by the CIRCUIT SELECTOR switch: CB talking and signaling, LB talking, and CB signaling. A buzzer is included for signaling from another set. The buzzer volume is controlled by the BUZZER VOLUME control. To signal another set, the hand generator crank must be manually turned.

The binding posts are used for hooking to another set or a switchboard.



73.185

Figure 12-30.—TA-312/PT set.

Maintenance

Maintenance is divided into two types: operation and shop.

Operator's maintenance is performed daily and consists of cleaning exterior surfaces with a lint-free cloth moistened with an approved cleaning solvent, checking the handset switch assembly for proper mechanical action (binding, scraping, looseness), and a normal operator's check (talk, receive, buzzing and buzzer).

Shop maintenance is performed weekly, and [illegible], is more extensive. Included are inspecting the external finish, cords, housing, carrying case, binding posts, and battery compartment for breaks, cracks, cuts, frays, fungus, dirt, moisture, corrosion, or general deterioration. The handset is also checked for loose receiver or transmitter elements.

The panel should not be removed nor the handset disassembled unless the maintenance checks indicate a malfunction of internal parts.

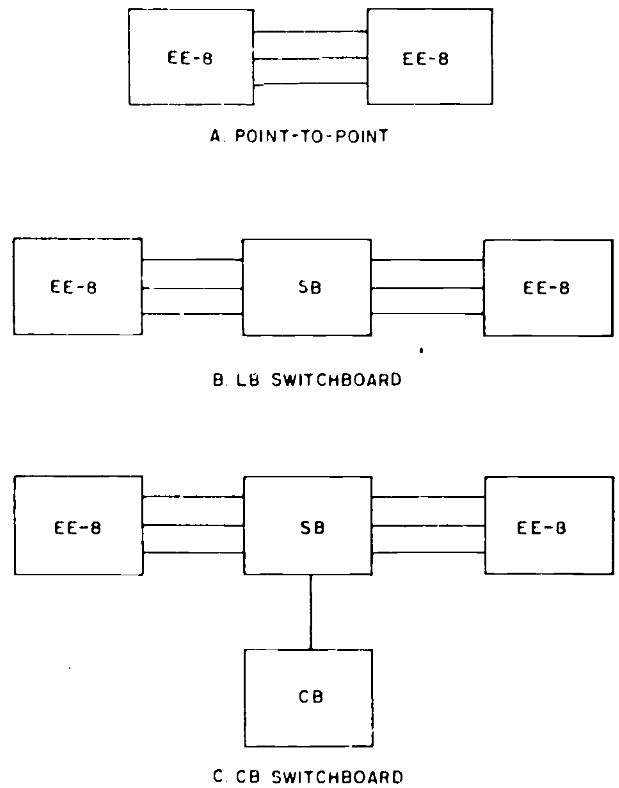
TELEPHONE EE-8

Telephone EE-8 is designed for use in point-to-point circuits and LB or CB switchboard systems. Depending upon the type of wire lines used, the range for point-to-point circuits is anywhere from 4.5 to 360 miles and in switchboard systems, the range varies from 0.9 to 72 miles.

Operation

Figure 12-31 diagrams the hookup for different uses. Figure 12-31, view A is a point-to-point circuit. Note that the telephones at both ends of the circuit are connected without intervening switchboards. Local batteries are used and the hand generator (a part of the telephone) is used for signaling.

Figure 12-31, view B (LB switchboard system) has the telephones set up through an LB switchboard to enable circuits to be set up between any telephone in the system. In this case, as in point-to-point circuits, local batteries are used and the hand generator is still used for signaling. The advantage over point-to-point systems is that several switchboards may be trunked together for a greater number of stations. The disadvantage is loss of talking range. (The ratio of range switchboard systems to point-to-point circuits is approximately 1:5 with trunked switchboards, or 1:2 using only one switchboard.)



26.288

Figure 12-31.—Telephone EE-8 system hookup.

CB switchboard systems (fig. 12-31, view C) use the common battery for signaling, though local batteries are still used for transmission. In this case, the hand generator is not used as the telephone lever switch is used to signal the switchboard operator.

Maintenance

In general, the same maintenance requirements prescribed earlier for the field switchboard apply here—inspect, tighten, clean and adjust. Since these sets are used outdoors, there are a few extra requirements. For instance, such things as dust, rapid weather changes, and excessive dampness all require more meticulous maintenance to keep the equipment dependable.

In addition, batteries will begin to deteriorate in as short a time as 48 hours with the handset switch left in the operate position. Even batteries in a stored telephone, with the switch in the OFF position, will begin to deteriorate in time, due to the physical breakdown of the battery caused by the pressure of the contact springs. Consequently, the handset switch must be turned off when not in use, and the batteries must be removed when the telephone is to be stored for any length of time.

AUTOMATIC TELEPHONE SYSTEM

All telephone systems in use at the present time fall into two categories: NONDIAL (MANUAL) SYSTEMS and DIAL SYSTEMS. Dial telephone systems are also called MACHINE-SWITCHING or AUTOMATIC SYSTEMS.

Any telephone system consists of a group of telephones with lines terminating at a central point (switchboard or central office) in such a way that any two telephones in the system may be connected with one another. A nondial or manual system is one in which connections must be made by hand by an operator. In a dial system connection is made automatically by means of electromechanically operated switching mechanisms remotely controlled by a dial, or calling device, at the telephone initiating the call.

There are two types of automatic dial telephone systems: the step-by-step type, which utilizes electromechanical switches to find and connect the number being called; and the relay system, which utilizes only the closing of electrical contacts to connect the lines in the system.

A step-by-step type may be expanded to handle a larger number of lines by simply adding additional equipment. An all-relay system is limited to the number of lines for which the unit is designed. Most of the dial installations used by the Armed Forces are of the step-by-step type. Some small installations use the all-relay system, but these are usually systems with not more than 100 lines.

The commonly used step-by-step dial central office is usually a 2-wire, 46- to 52-volt common-battery, fully automatic type telephone system. Two-wire means that no matter how many wires are used between units of switching equipment inside the central office, only two wires extend between the central office and the telephone served by it. The two wires may be enclosed in a cable to form a cable pair. They may be a twisted insulated-wire pair, or they may be two bare wires on insulators. The term "46- to 52-volt common-battery" refers to the source of electrical energy provided at the central office to operate the automatic equipment, and to supply transmission (talking) and signaling (ringing) current to the outside telephone lines. The voltage range indicated means that the equipment will operate efficiently over a range of from 46 to 52 volts, direct current.

The switching equipment in a step-by step dial central office operates directly from dial pulses transmitted from the pulse-sending device, or dial, of the calling telephone. The dial pulses are interruptions of current caused by the alternate opening and closing of pulse springs in the dial mechanism. Figure 12-32 shows the circuit of a typical dial telephone with the contacts in talking position. Figure 12-33 shows front and rear views of a typical dial.

In a step-by-step dial telephone system each set, or series, of dial pulses (sometimes called train of pulses or pulse train) corresponding to each digit dialed by the telephone users extends a connection one step at a time through the switching equipment to the called telephone. The wipers, or contacting arms, of numerical (dial controlled) stepping switches establish the proper connections at the central office. These wipers are moved one step at a time by electromagnets operated by pulses from the dial of the calling telephone. This is how the step-by-step dial telephone derives its name.

Figure 12-34 shows a step-by-step switchroom. The can-like containers house switching equipment consisting of two-motion Strowger switches (fig. 12-35).

STROWGER SWITCHES

The Strowger switch is an electromechanical product that extends the connection from the calling to the called telephone. It consists of a bank of electrical contacts arranged in 10 levels with 10 sets of contacts to a level. The wipers, which make contact with the selected

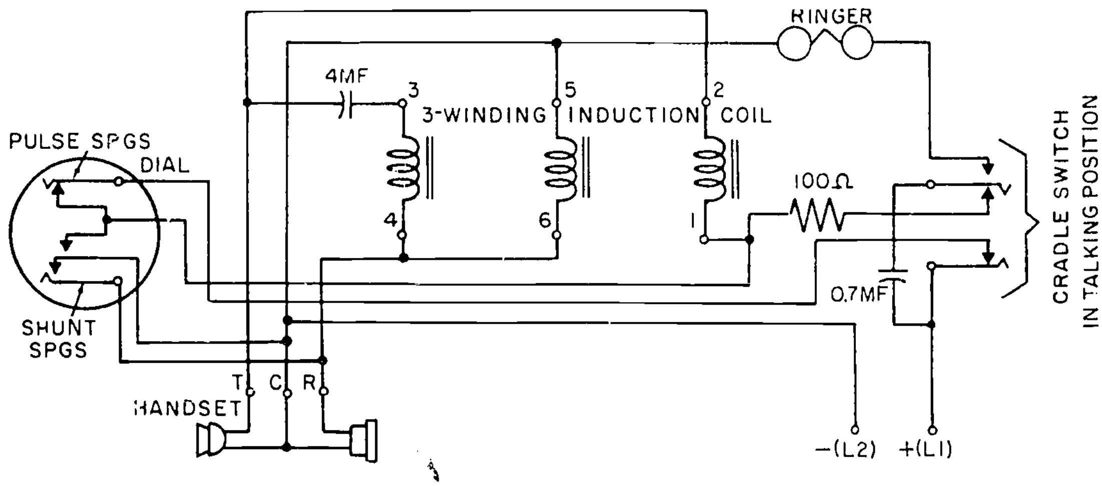


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Figure 12-32.—Circuit of representative dial telephone, talking position.

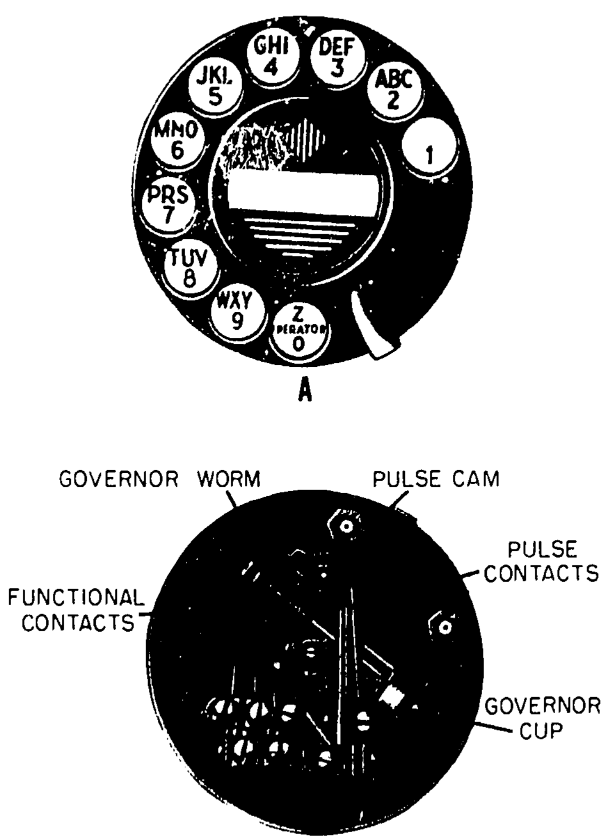

Figure 12-33.—Front and rear views of telephone dial. 7.85

set of contacts, are connected to the switch shaft. The switch mechanism elevates the shaft (and wipers) any number of steps from 1 to 10. When the shaft is released, it rotates backwards under the influence of a spring and then returns to normal under the pull of gravity. The Stowger switch, because of the up and around movement, is referred to as a two-motion or step-by-step switch. It is the basic switch of the step-by-step system, and with a few mechanical and electrical variations, is used as a linefinder, connector, and selector.

The LINEFINDER finds the line of the telephone station seeking to make a call and extends the line to the selector for all systems in excess of 100 lines. The linefinder mechanism is controlled by the finder control relays. The impulses to step the mechanism up and around are furnished by interrupter springs on the vertical and rotary magnets. The finder switch is referred to as a NONNUMERICAL type of Strowger switch, because its operation is automatic and not under the control of dial impulses. The linefinder switch depends on its associated line-and-cutoff relays, group control relays, and distributor relays.

The LINE-AND-CUTOFF RELAY is a relay individual to the line with which it is associated (in contrast to the switch circuits which serve many lines and the control circuits which serve many switches). For example, when a call is initiated by a telephone, the line-and-cutoff relay functions to: (1) apply ground (positive side of the battery) to start the linefinder control relays

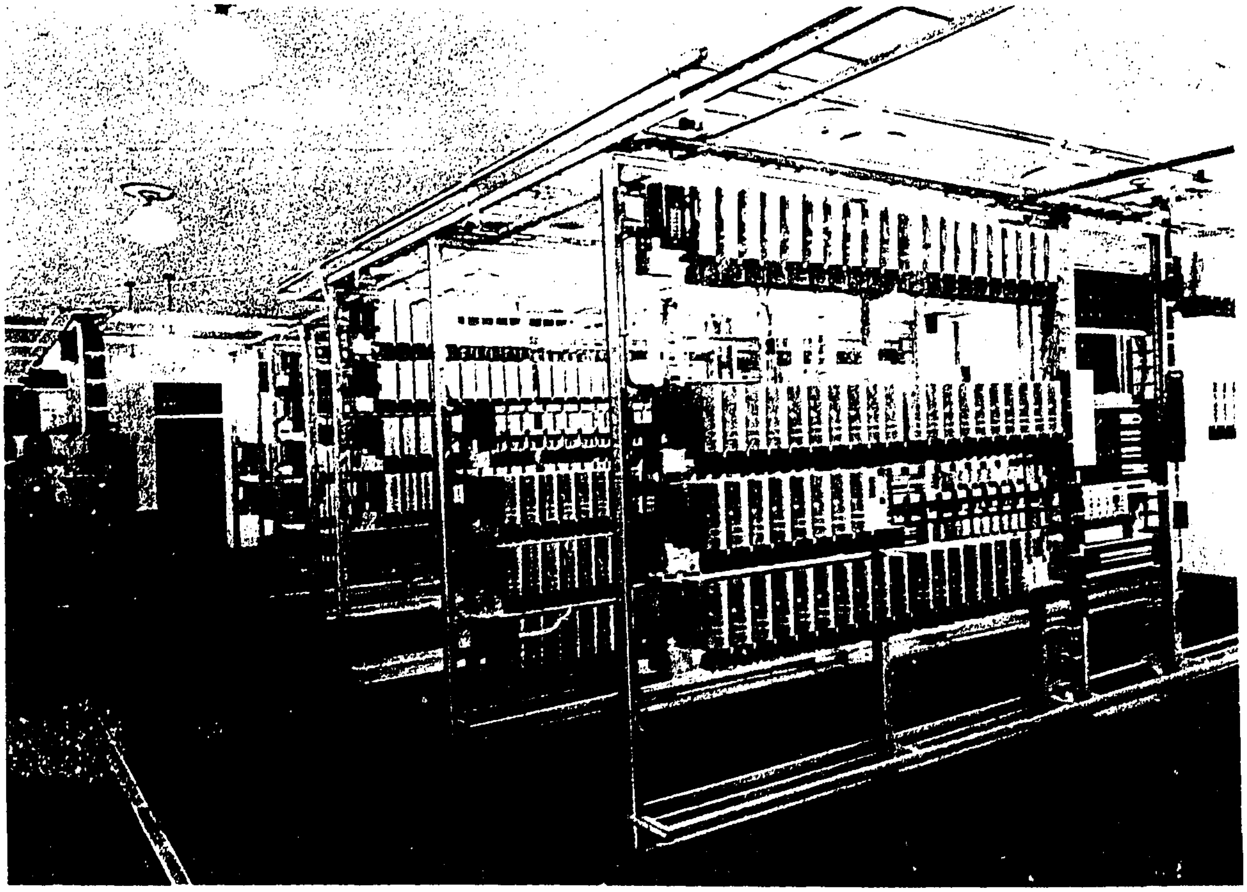

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Figure 12-34.—Step-by-step dial telephone switchroom.

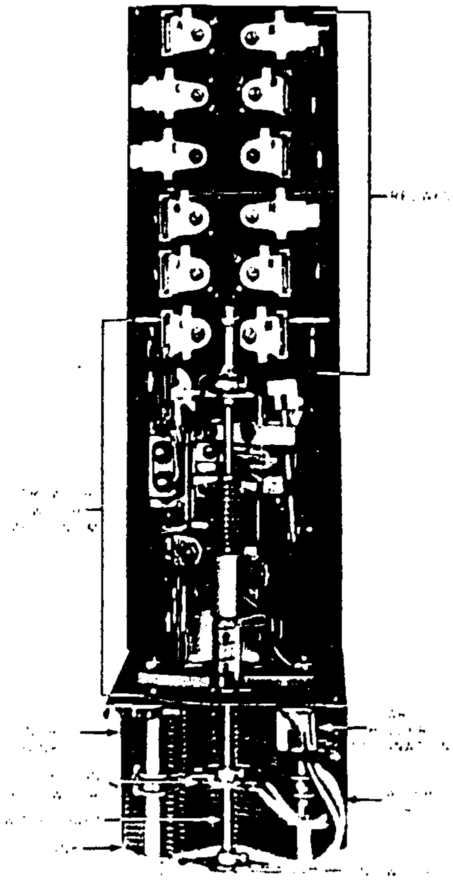
to actuate a linefinder switch to hunt for the calling line; (2) mark a contact in the bank of a linefinder by placing battery (negative voltage) on the contact so that when the linefinder wiper encounters battery the linefinder will know it has located the line it is trying to find.

The SELECTOR extends the line of the calling telephone to the connector. The vertical stepping of the selector is controlled by the first digit dialed at the calling telephone, and the rotary stepping is controlled by interrupter springs on the rotary magnet.

The CONNECTOR extends the line of the calling telephone to the line of the called telephone. The impulses transmitted from the dial of the calling telephone actuate the connector mechanism to step the wipers up and around to the set of contacts associated with the called telephone station. A connector switch is referred to as a NUMERICAL type of Strowger switch because it operates under the control of dial impulses.

The simplest arrangement for establishing a connection between two telephones consists of two elements, a linefinder and a connector, and is called a link. This combination performs satisfactorily in an exchange servicing less than 100 telephone lines. When additional lines are required, first, second, third, and so on, selectors are added. A group of links is called a bank.

Figure 12-36 shows a typical wiper and terminal bank for a two-motion stepping switch that operates vertically on the first operation and horizontally on the second operation.

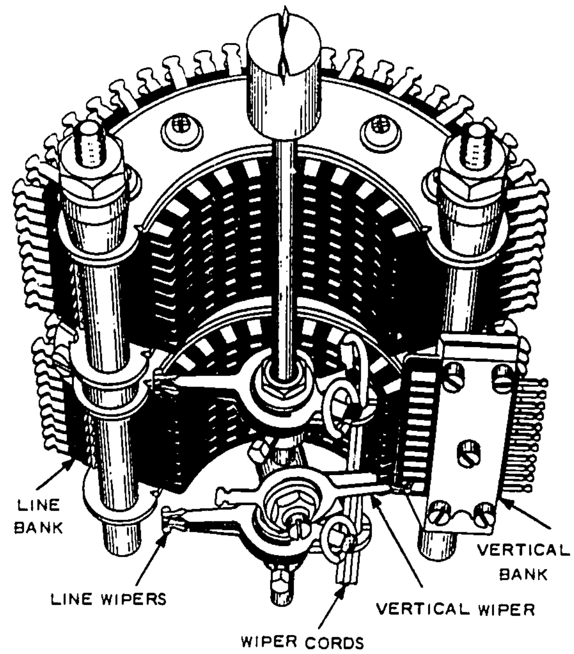


27.336
Figure 12-35.—Strowger switch.

100-LINE SYSTEM

Figure 12-37 shows a schematic diagram of two linefinder-connector links for a basic 100-line linefinder-connector system. One such link is required for each simultaneous conversation. For example, if the normal operation of the system shows an average of 20 simultaneous conversations, then 20 links are needed in the bank in order to handle all calls. Each link is like a cord circuit of a manual telephone system. Notice that the 100 lines (indicated by the lines numbered 44 and 75) are connected parallel to all linefinders as well as to all connectors in the bank.

Since each of the 100 lines is connected in parallel to all of the linefinders in the bank, any idle linefinder in the system can automatically hunt for and find the line of any telephone

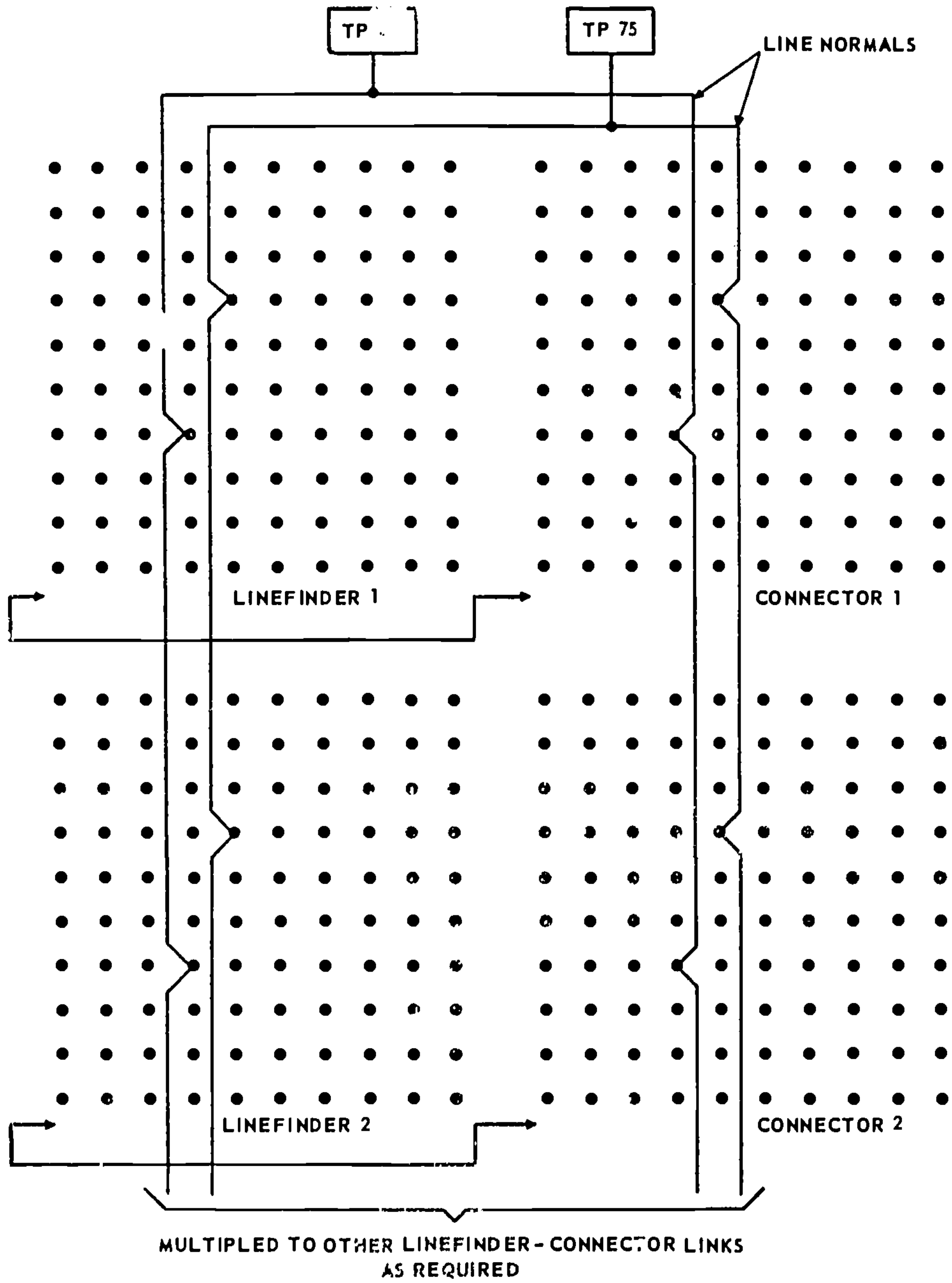


73.189
Figure 12-36.—Wipers and terminal bank.

in the system when the handset of that particular telephone is lifted from the cradle.

Because each of the 100 lines of the system is also connected in par 'lel with each of the connectors in the bank, .. e connector linked with the linefinder can raise and rotate its wipers, under control of dial pulses from the calling telephone, to complete a connection to any one of the 99 other telephones in the 100-line basic linefinder-connector system. Notice that the leads from the connector banks back to the 100 lines of the linefinder bank are called line normals. Line normals are also called normals, normal wires, or normal cables.

To trace a typical call through the 100-line basic linefinder-connector system, assume that a telephone user at telephone No. 44 wishes to call telephone No. 75. When the handset of telephone No. 44 is lifted from the cradle, an idle linefinder (in this example linefinder No. 1) automatically elevates and rotates its wipers until they come to rest at contact set No. 44. The linefinder automatically extends the calling line through to the connector which is linked to the linefinder. The connector returns a dial tone to the calling telephone, to signal the user that the digits of the called telephone number



NOTES

1. ONLY TWO OF THE 100 TELEPHONE LINES ARE SHOWN ALTHOUGH EVERY ONE OF THE 100 LINES HAS A MULTIPLE APPEARANCE AT THE BANKS OF EACH LINEFINDER AND CONNECTOR IN A LINK.
2. ONLY TWO LINEFINDER-CONNECTOR LINKS ARE SHOWN. EACH OF THE 100 LINES IS MULTIPLED SIMILARLY TO OTHER LINEFINDER-CONNECTOR LINKS AS REQUIRED.

7.80

Figure 12-37.—Linefinder-connector links.

(No. 75 in this example) may be dialed. When the digits 7 and 5 of the called telephone are dialed, the connector operates in response to the resulting pulses from the dial of the calling telephone and raises its wipers to the 7th contact level, and then rotates its wipers to the 5th contact, so that the wipers come to rest on bank contact No. 75.

The connection is then completed from calling telephone No. 44 through linefinder-connector link No. 1, and over the line normals of line No. 75 to telephone No. 75. The connector then tests called telephone No. 75. If the called telephone is idle (not in use) the connector transmits ringing-tone current over the called line to operate the ringer of the called telephone. If, however, the called telephone is in use, the connector transmits busy-tone current to the calling telephone to advise the caller that the called telephone is busy. The busy-tone signal advises the calling telephone user to replace the handset on the cradle, and to try to make the call again a few moments later.

1000-LINE SYSTEM

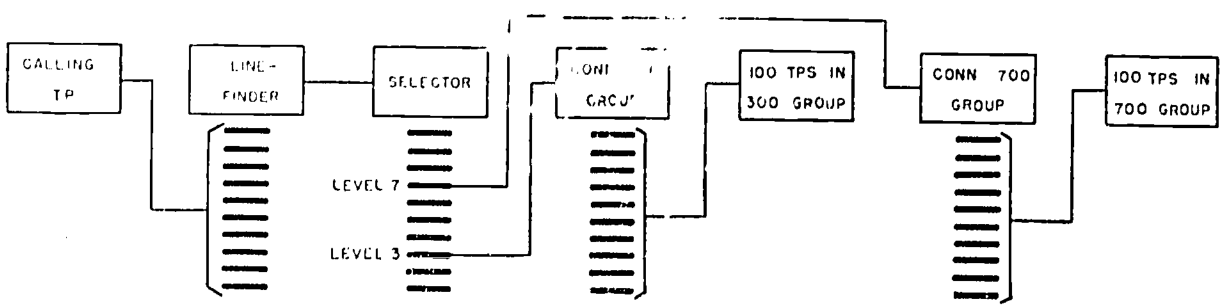
Systems with a capacity of more than 100 lines require the use of an additional two-motion stepping switch called a selector. The mechanical structure of a selector resembles that of a linefinder and a connector. The banks, the method of bank contact numbering, the wipers, and the two-motion stepping mechanism of a selector are practically the same as those of the linefinder and connector.

The selector is introduced in the switch train between the linefinder and the connector (fig. 12-38). The linefinder and the selector form the link. One such link is required for each conversation to be held. The linefinder searches for the calling line and extends it to the selector. The selector extends the calling line to a succeeding connector in the switch train. The connector, or last switch in the switch train, extends the calling line through to the called line, and the call is completed in the usual manner.

Unlike the linefinder but like the connector, the selector faces forward toward the called line. In a basic 1000-line system, the telephone lines are associated into 10 groups of 100 lines each. It is the function of the selector to select the group of 100 lines (hundreds group) in which the called line is located. The connector selects both the subgroup of 10 lines (tens group) in which the called line is located, and the particular line itself (unit line) in that group.

This straightforward 1000-line system requires telephone numbers containing three digits each, the selector operating in response to the pulses of the first number dialed and the connector responding to the following two numbers. A 1000-line central office thus has 10 connector groups, one for each hundreds group. Only two of the ten connector groups are shown in figure 12-38: the group of connectors that serves the 100 lines in the 300 group, and the group of connectors that serves the 100 lines in the 700 group. The term "300 group" refers to lines with telephone numbers from 300 to 399; the term "700 group" refers to lines with numbers from 700 to 799.

To illustrate the operation of the 1000-line system: assume that a telephone user at the calling telephone in figure 12-38 wants to call telephone number 344. When he removes the handset from the cradle, an idle linefinder hunts for and finds the calling line, and extends the



7.82

Figure 12-38.—Block diagram of 1000-line system, showing selector.

calling line to the selector linked to that specific linefinder. The selector, when grasped, returns a dial tone to the calling telephone user, who then dials first the digit 3 (the hundreds digit). Three pulses from the dial of the calling telephone cause the selector to raise its wipers to contact level 3. The selector then automatically rotates its wipers over the contacts on level 3, searching for a contact set (trunk) to which an idle connector in the 300 group is connected. The sets of wires from the selector to the connectors are called trunks. The automatic selection of an idle trunk is called trunk hunting.

Upon finding an idle trunk on the dialed level (3 level in this case), the call is extended by the selector through to the connector. When the digits 4 and 4 are dialed, the connector completes the call in the usual manner.

10,000-LINE SYSTEM

The procedure for a central office with a capacity of more than 1000 lines follows the same pattern as that for the 1000-line system, except that an additional selector is added in the line between the linefinders and the connectors. The first selector returns the dial tone, steps its wipers up to the dialed level under control of the first digit dialed (the thousands digit), and automatically rotates the wipers over the dialed level until they seize a trunk to an idle selector. The second selector elevates its wipers to the dialed level under control of the second digit dialed (the hundreds digit), and then automatically rotates the wipers until they seize a trunk to an idle connector. The connector completes the call in the usual manner. All this is illustrated in figure 12-39.

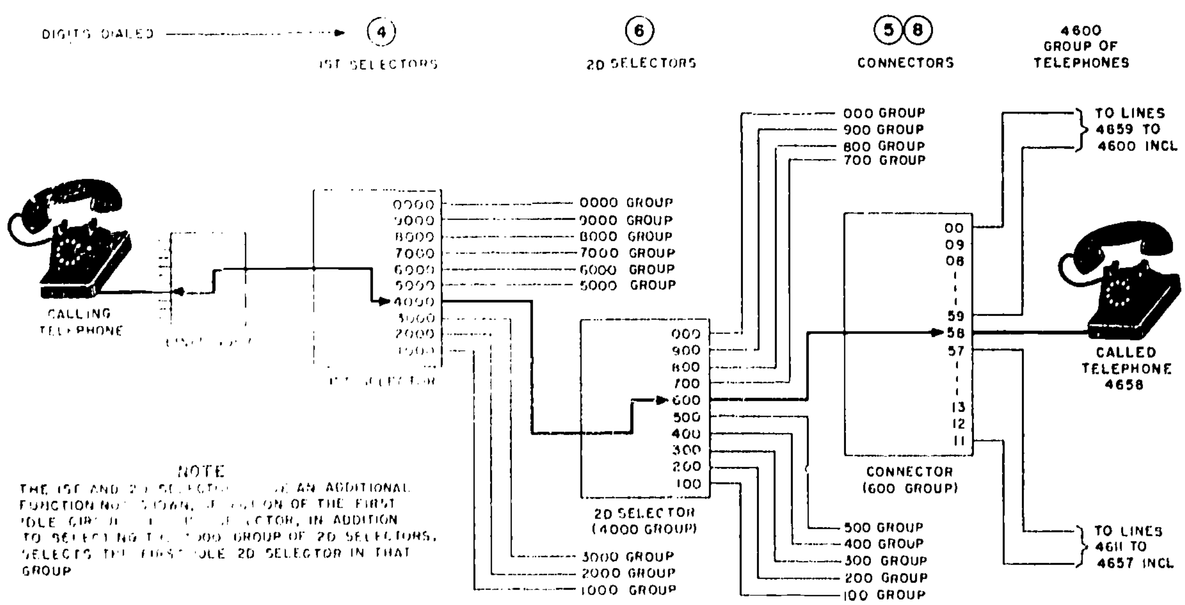
TROUBLESHOOTING

Tables 12-1 and 12-2 show common troubles, symptoms, and corrections in typical step-by-step dial central-office equipment.

CROSSBAR SWITCHING SYSTEM

The crossbar switching system has two main divisions of equipment, each with different functions. The two divisions of equipment are: the control equipment and the switching network.

The CONTROL EQUIPMENT establishes the talking path by causing the proper switch to operate. The SWITCHING NETWORK consists mostly of crossbar switches through which the talking paths are set up.



73.190

Figure 12-39.—Simplified 4-digit dial system.

Table 12-1.—Troubles Indicated by Supervisory Signals

Symptoms	Probable troubles	Corrections
Fuse alarm operates on power distributing fuse panel.	Short circuit or overload in power circuits.	Test circuit for trouble. Repair equipment and replace power fuse and alarm fuse.
	Defective alarm fuse.	If power fuse was not blown, replace alarm fuse.
Motor-generator control panel fuse alarm operates.	Open charging fuse or fuses.	Clear trouble in circuit, if any. Replace fuse and associated alarm fuse.
	Defective alarm fuse or fuses.	Replace alarm fuse.
	Open reverse-current relay fuse.	Test relay circuit and replace fuse.
Main battery fuse alarm operates.	Open main fuse.	Clear trouble in circuit, if any. Replace main fuse and associated alarm fuse.
	Defective alarm fuse.	Replace fuse.
Voltage alarm operates because of low voltage.	Main battery discharge or failure.	Check battery cells. Adjust motor-generator controls to charge battery.
	Motor-generator voltage too low.	Adjust generator voltage controls.
	Motor-generator paralleling panel fails to start No. 2 machine.	Check control circuits and motor generator.
	End-cell control switch fails to switch end-cells into main battery circuit.	Clean and repair end-cell control switch.
	Open LV relay coil or resistor, or contact springs out of adjustment.	Replace relay coil or relay. Adjust contact springs.
Voltage alarm operates because of high voltage.	End-cell control switch fails to switch end-cells out of main battery circuit.	Clean and repair end-cell control switch.
	Generator voltage too high.	Adjust generator control. Check control circuit and relays.
	Motor-generator control panel fails to cut No. 2 machine out of circuit when power load diminishes.	
Ringing current supervisory alarm operates steadily.	No. 2 ringing machine fails to start automatically when No. 1 machine shuts down.	Clean contacts on transfer relays. Test transfer relays.
		Test automatic starting switch.
		Clean ringing machine commutator.
		Replace commutator brushes.
	Generator hold-up relay (GEN HU) fails to operate.	Replace relay coil or relay.
Supervisory fuse alarm operates.	Open fuse or fuses in ringing, tone, or signal circuits.	Remove open fuse. Check circuit and clear trouble. Replace fuse.

73.248.1

Table 12-1.—Troubles Indicated by Supervisory Signals—continued

Symptoms	Probable troubles	Corrections
Group fuse alarm operates.	Open fuse or fuses on shelf fuse panel.	Remove open fuse. Check circuit and clear trouble. Replace fuse.
Release alarm operates.	Linefinder, connector, or selector failed to restore to normal position when released.	Restore switch manually. Busy out the defective switch. Repair, test, and place in service.
CDF (central distribution frame) lamps operate.	Operated heat coil or coils.	Test and clear line. Replace heat coils.
Permanent signal (PERM) on connector shelf.	Called party fails to disconnect.	Locate affected switch. Challenge on the line. Test line and use howler. Open line by removing heat coils. Make out trouble report.
	Calling party fails to disconnect.	Same as above.
	Short circuit or ground appears on line after connector has seized it.	Test as above. Open line by removing heat coils. Fill out trouble report.
Step signal (ST SIG) lamp glows on linefinder shelf and alarm buzzer operates.	Linefinder fails to step from normal position and hunt for calling line.	Locate faulty switch. Operate busying switch to remove faulty switch from circuit. Repair switch, test, and replace in service.
	Defective relay A-3 in group relays.	Clean and adjust contacts.
Supervisory signal lamp (SUPY) glows on selector shelf.	Calling party fails to dial or hang up after selector switch has been seized.	Challenge seized line. Test line and use howler. Fill out trouble report. Dispatch repairman to telephone set in question.

73.248.2

Table 12-2.—Troubles Indicated by Service Complaints

Symptoms	Probable troubles	Corrections
Noisy, intermittent, or poor transmission.	Wiper tips worn too thin.	Replace wipers.
	Insufficient tension on wiper tips.	Adjust wiper spring tension.
	Broken conductors in wiper cords.	Replace cords.
	Dirty switch bank contacts.	Clean switch bank contacts.
	Dirty relay contacts or insufficient contact spring tension	Clean relay contacts. Adjust contact spring tension, if required.

73.249.1

Table 12-2.—Troubles Indicated by Service Complaints—continued 73.249.2

Symptoms	Probable troubles	Corrections
Cannot make outgoing calls.	All trunks busy.	Instruct user to place call later.
	Linefinder or connector permanents, or off-normals.	Clear troubles and restore blocked switches.
	Defective telephone line equipment.	Repair defective line equipment.
	Defective line relay coil.	Replace relay coil.
Calling party does not receive dial tone.	Line relay contacts not making.	Clean relay contacts. Adjust contact spring tension, if required.
	Open resistor in linefinder start circuit.	Replace resistor.
	Fault in group relay circuit.	Check group relays.
	Rotary cam springs on first selector not making contact.	Clean and adjust cam spring contacts.
	Selector relay contacts not completing dial tone circuit.	Inspect for dirty or pitted contacts. Clean and adjust.
	All linefinders in group busy.	Advise telephone user to restore handset and to place call again.
Calling party does not receive busy tone.	Connector relay contacts not completing busy tone circuit.	Inspect for dirty or pitted contacts. Clean and adjust.
	Open capacitor in busy tone circuit.	Replace capacitor.
Calling party receives busy tone before completion of dialing.	All trunks are busy.	Check trunks for possible trouble. Advise telephone user to place call at less busy time.
Calling party does not receive ring-back tone.	Connector relay contacts not completing ring-back tone circuit.	Inspect for dirty or pitted contacts. Clean and adjust.
	Open capacitor in ring-back tone circuit.	Replace capacitor.
Bell does not ring.	Open-circuited or short-circuited line crossed with battery.	Test the line from the CDF.
	Open-circuited ringer.	Send repairman to the telephone set.
	Ringing current not being supplied to the line.	Check operation of the ringing group relays. Check each connector ringing relay in group. Clean and adjust relay contacts, if required.
Called party does not answer.	Same as above.	Same as above.
Calling party cannot hear called party.	Connector relay contacts not completing transmission circuit.	Make routine test of connectors. Inspect, clean, and adjust relay contacts.
	Reverse-battery relay does not supply battery to called party.	Inspect, clean, and adjust contacts.
	Open capacitor or capacitors	Replace the capacitors.

Table 12-2.—Troubles Indicated by Service Complaints—continued

Symptoms	Probable troubles	Corrections
	in connector transmission circuit.	
Called party cannot hear calling party.	Relay contacts faulty in preceding switches.	Test selectors, line finders, and line relays.
	Relay contacts on connector preceding switches not completing transmission circuit.	Make routine test of connectors. Inspect for dirty or pitted relay contacts. Clean and adjust.
	Reverse-battery relay does not supply battery to calling party.	Check, clean, and adjust contacts.
	Open capacitor or capacitors in transmission circuit.	Replace the capacitors.
	Relay contacts faulty in preceding switches.	Test selectors, linefinders, and line relays.

73.249.3

When you dial, you tell the control equipment the number you want. The control equipment then finds the proper path through the switching network and closes the necessary switches to complete that path.

MAJOR COMPONENTS

Major components of a crossbar office, organized according to function, are: a marker, an originating register, a number group frame, and a sender.

The MARKER is the brain of a crossbar. It marks points in the switching network through which calls must go and selects and establishes paths between these points. This operation is performed at the rate of about one-half second per connection.

An ORIGINATING REGISTER gives you a dial tone and remembers the number you dial—using relays and switches. Incoming registers perform the same function for calls from other central offices.

The NUMBER GROUP FRAME is a mechanical telephone directory which knows the number of every telephone in the central office. It knows to which terminals on which line link frame each telephone is connected and is prepared to give out this information anytime it is asked for by the marker. The SENDER transmits numbers, in special codes, that other offices are set up to receive. Different types of senders are provided to transmit signals to the different types of central office, such as step-by-step, crossbar, and manual offices.

SWITCHING NETWORK

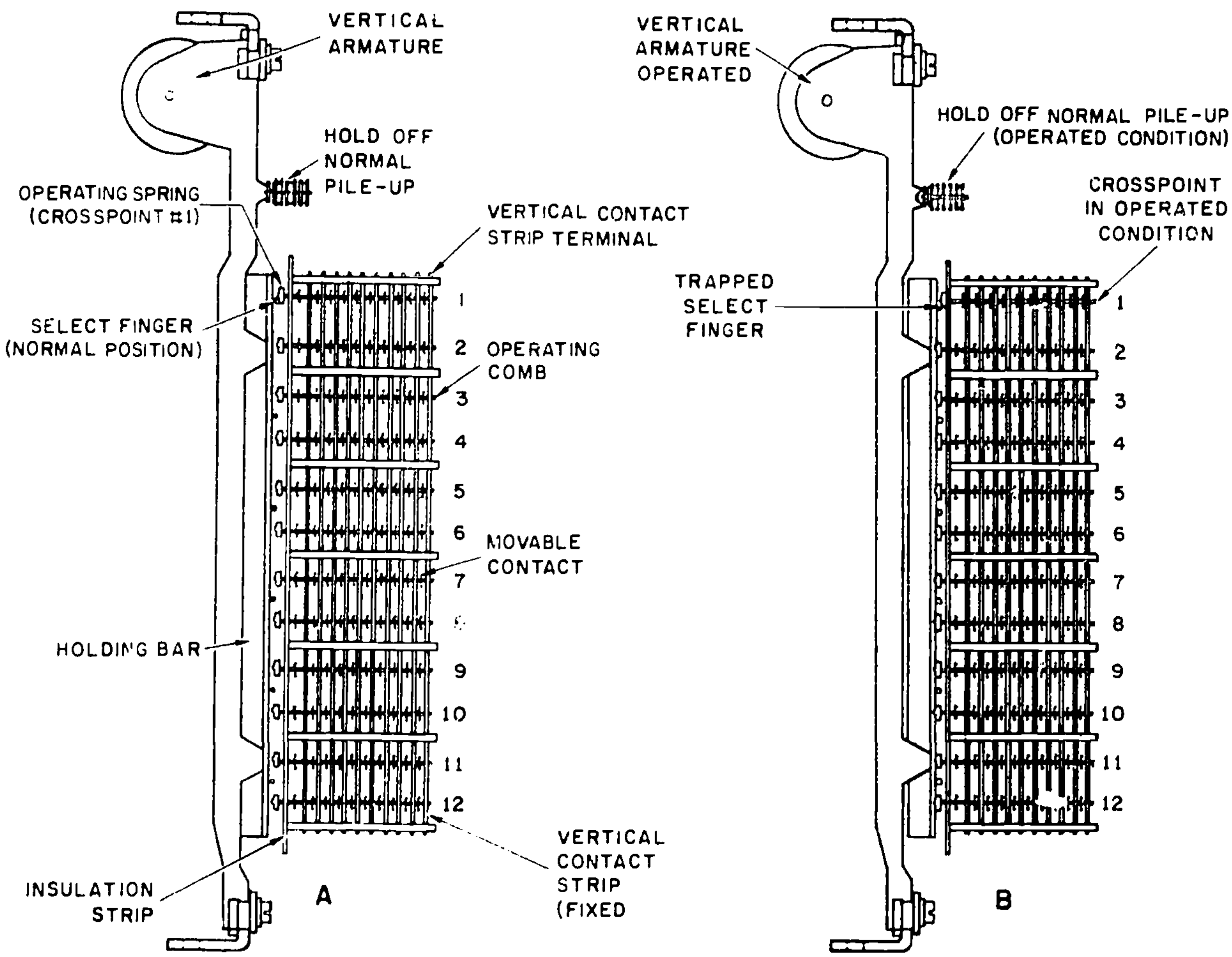
Two important units of the switching network are the line link frame and the trunk link frame.

The LINE LINK FRAME is a unit consisting principally of crossbar switches, to which telephones are connected. A line link frame is the first link in the call you make; it is also the last link since any telephone you call is connected to a line link frame.

The TRUNK LINK FRAME is a unit to which trunks in the central office are connected. A trunk is simply a telephone line or circuit leading from one place to another. Such a line, which begins and ends in the same central office, is called an intra-office trunk. Lines on circuits which lead to or from other central offices are called outgoing or incoming trunks.

CROSSBAR SWITCH

The crossbar switch, which is the key unit of a crossbar switching network, differs from the step-by-step switch as radically as the two systems differ from each other. A crossbar switch is a rectangular device with horizontal and vertical bars crossing each other



73.341

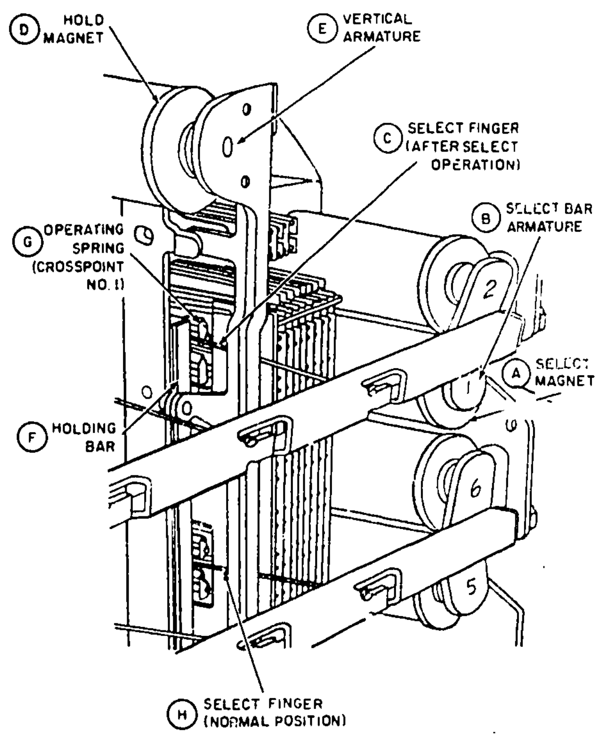
Figure 12-40.—Vertical unit after select operation; vertical unit after hold operation.

in a latticework fashion. These bars are mounted on a frame so that they can move (pivot or tilt) with the movements controlled by electromagnets. (See figs. 12-40 and 12-41.)

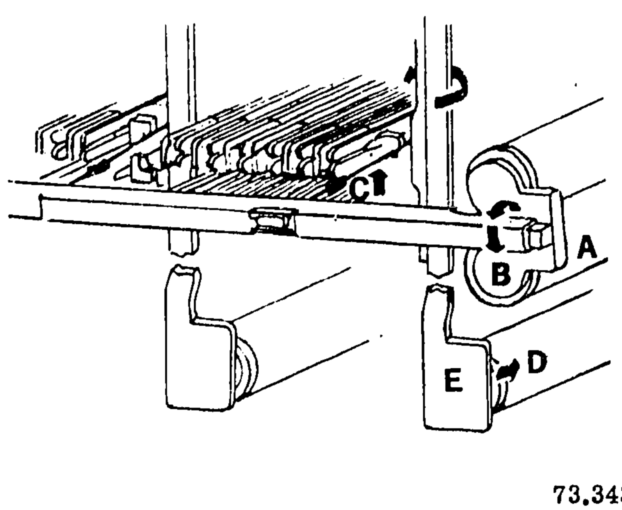
The principal components of the switches are relay type sets of contacts mounted one above the other behind the vertical bars. These sets of contacts are called crosspoints. To close a set of crosspoints and thereby complete a connection through the switch, first a horizontal bar moves and then a vertical bar (fig. 12-42). The switch design makes it possible to produce multiple connections. When connections are made, electrical paths are established as indicated in (figure 12-43.) Only three completed paths are shown, but as many could be made simultaneously as there are horizontal paths—10 in this case. The availability of so many connections is an important asset to the central-office switching networks.

TRACING A CALL

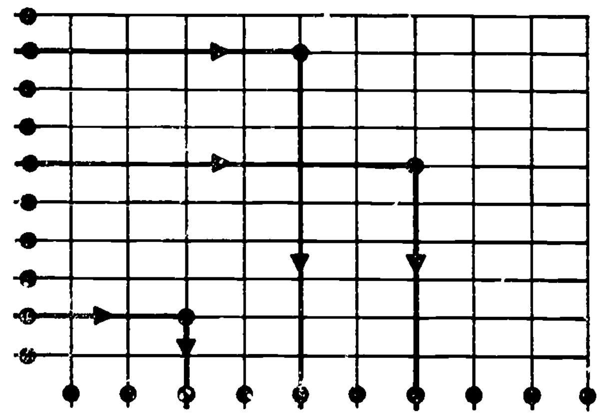
The block diagrams in figures 12-44 through 12-48 show how the different units in a crossbar



73.342
Figure 12-41.—Sectional view of crossbar switch.



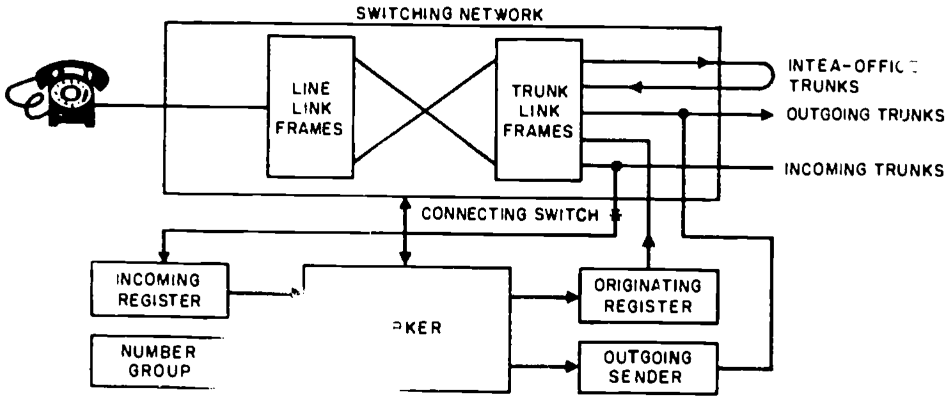
73.343
Figure 12-42.—Perspective view of part of a crossbar switch.



73.344
Figure 12-43.—Electrical paths established when connections are made in a crossbar switch.

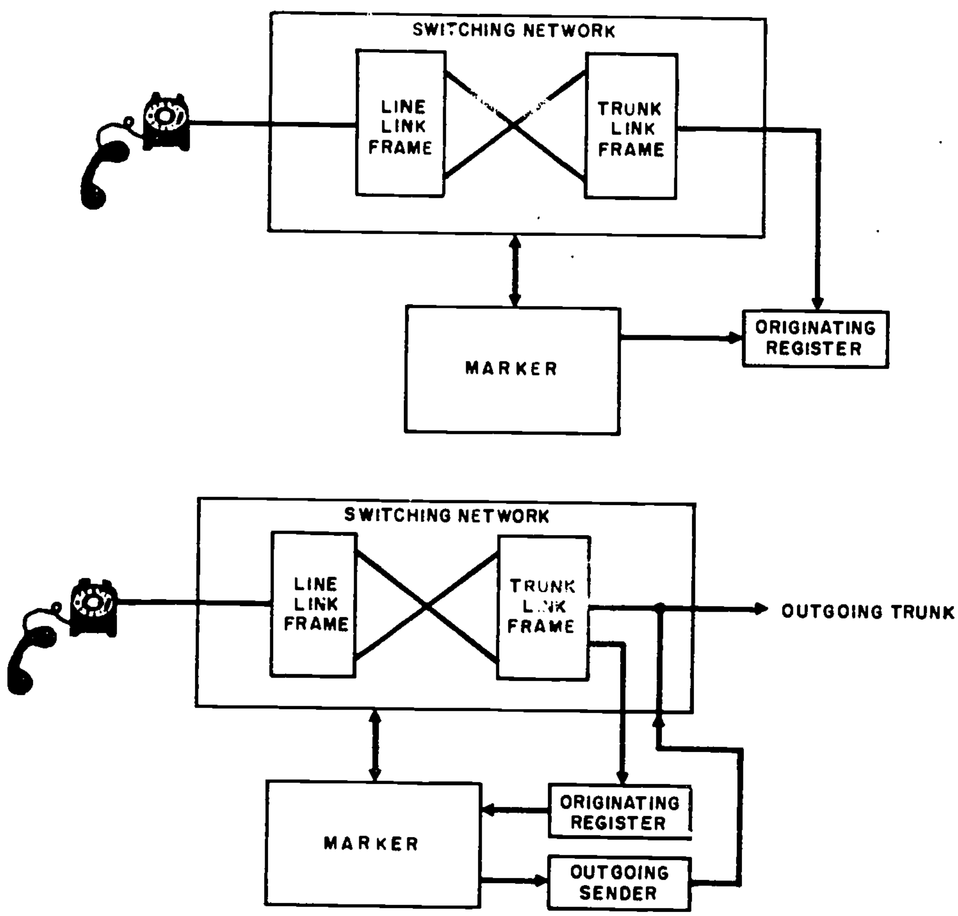
office are inter-connected (through crossbar switches) for an intra-office call. When you pick up your handset you are connected to your crossbar switch in a line link frame. (See fig. 12-44.) A marker is signaled and connects you to an originating register. The marker now disconnects itself to handle other calls. You hear the dial tone and dial the number you want which is recorded by the relays of the originating register.

The originating register now connects to an idle marker and transmits the number you want to the marker. (See fig. 12-45.) The first three digits of the number (known as the office code) tell the marker the name of the office called. Assume that the called number is in another central office. The marker, therefore, disconnects your line from the originating register, connects the proper sender to the proper outgoing trunk, and connects your line to the trunk through the line link and trunk link frames. The sender transmits the number you want to the other central office. In this second central office (figure 12-46), an incoming register records the number from the distant sender after which it connects to a marker. The marker receives the number from the register. The marker must now locate the called number in its office. To do this it checks the number group frames (fig. 12-47). This electrical telephone directory tells the marker the location of the number, the right line link frame, the crossbar switch, and so on. The number group frame and incoming register are dismissed by the marker, which now connects the incoming



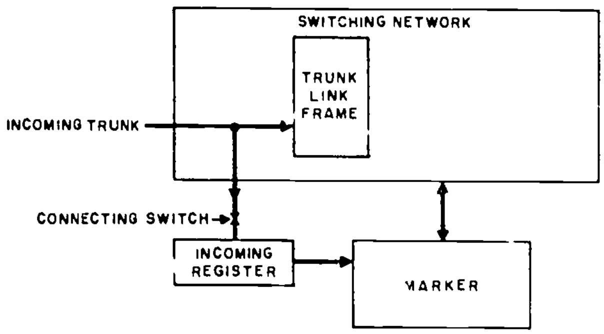
73.345

Figure 12-44.—Switching network.

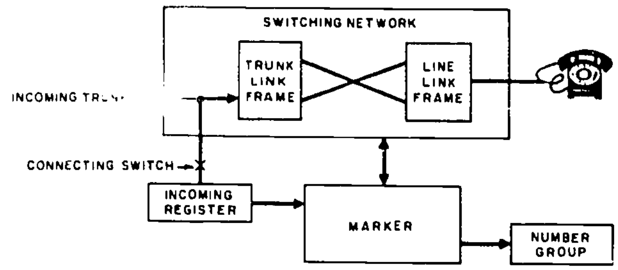


73.346

Figure 12-45.—Block diagram showing how different units in a crossbar office are interconnected for an intra-office call.



73.347
Figure 12-46.—Path of call in second central office.



73.348
Figure 12-47.—Marker connects the incoming trunk to the called number through a trunk link frame and line link frame.

trunk to the called number through a trunk link frame and line link frame. Since the connection is now complete, the marker disconnects itself and goes on about other business. The incoming trunk rings the called line. The call is complete when the called party lifts the receiver (fig. 12-48).

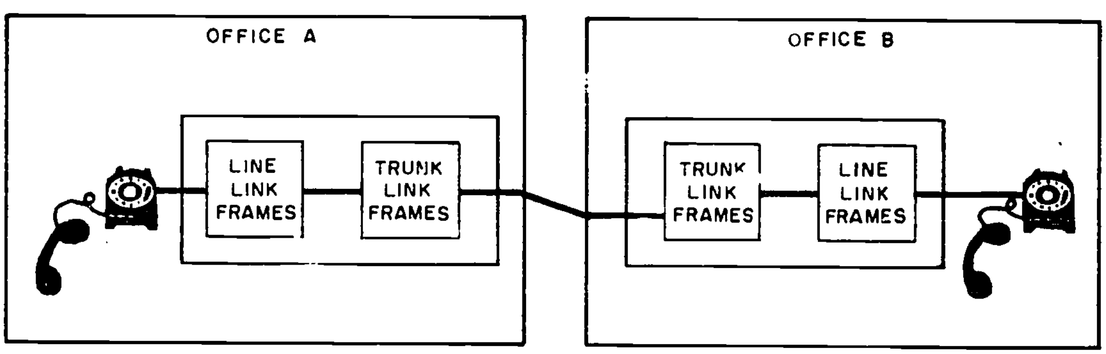
INTEROFFICE COMMUNICATIONS SYSTEMS

An interoffice communicating system is used to transmit orders and information among offices that are only a short distance apart. Frequently such offices are in the same building. Intercoms are not used at all advanced bases; if they are used, the job of installing and maintaining them usually falls to the CE.

The installation of an intercom system can be accomplished easily by following instructions that come with the set and using wiring diagrams.

An intercom system consists of one or more master stations, a junction box, one or more remote speaker units, and the wire necessary to make the connections. One type of intercom set is shown in figure 12-49. The master station has a capacity of 6 remote-microphone units; however, if one or more of the remote units are connected to the call-in circuit, the capacity of the system is only 5 remote stations.

The basic parts of the master station shown consist of a 3-tube chassis, a speaker-microphone, and a selector switch panel (fig. 12-50). The parts are installed in a wooden cabinet. A combination volume control and ON-OFF switch is mounted directly below the selector switch panel. The pilot light is illuminated at all times when the switch is on. A 3-position



73.349
Figure 12-48.—Completed connection through switching newtorks of two crossbar central offices.

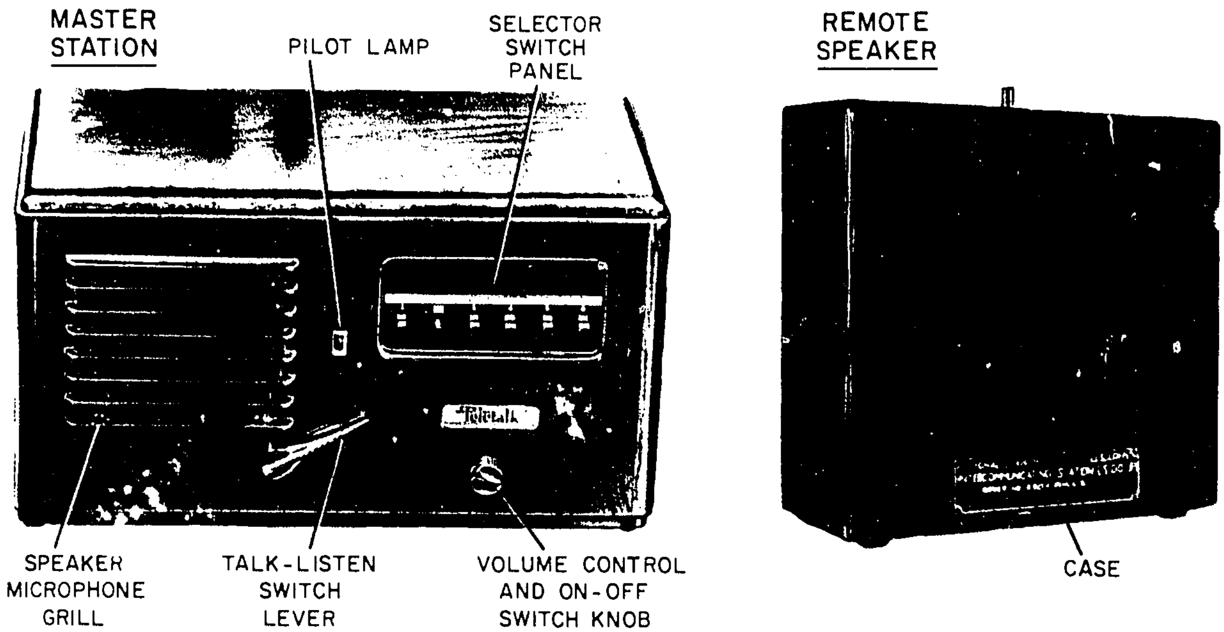


Figure 12-49.—Intercom set. 26.286

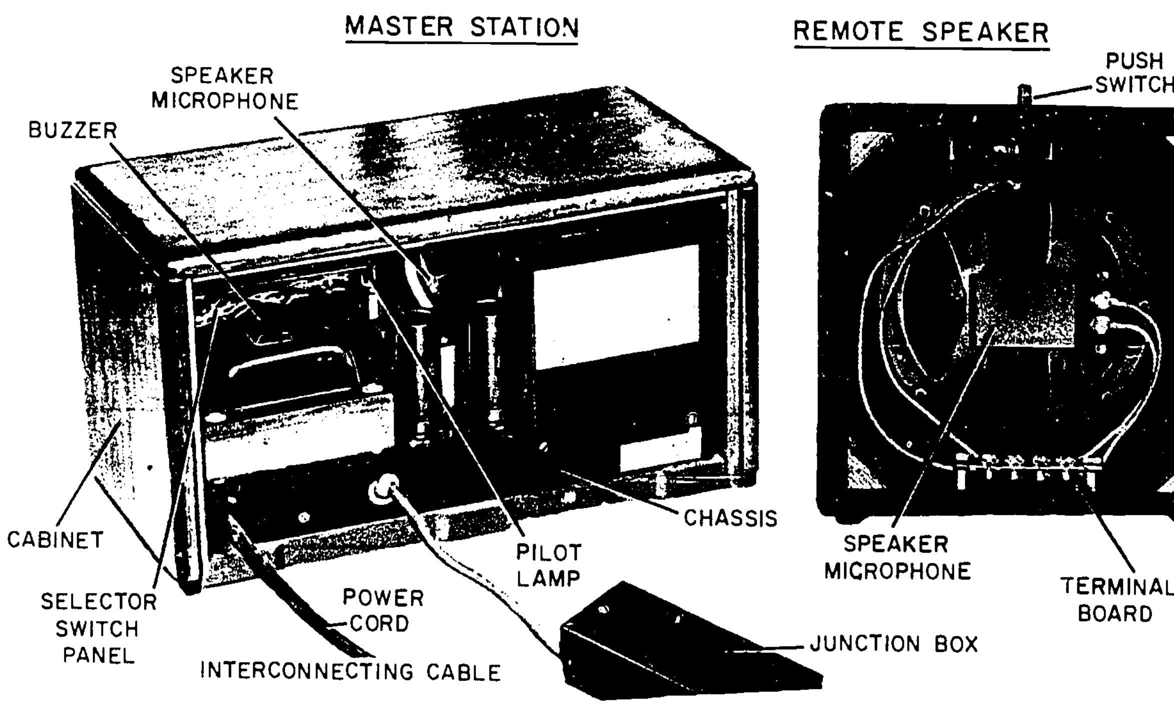


Figure 12-50.—Intercom set, rear view. 26.287

switch at the center of the cabinet front controls talk-listen or idle position. The speaker-microphone is mounted inside the cabinet behind the grill on the front panel. A junction box, used for interconnection to remote stations, is attached to the chassis by flexible cable. An a-c power cord is attached to the chassis.

The remote unit consists of a speaker-microphone mounted in a wooden cabinet, a push switch for signaling the master station when intercommunications is desired, and a terminal board for interconnection to the master station.

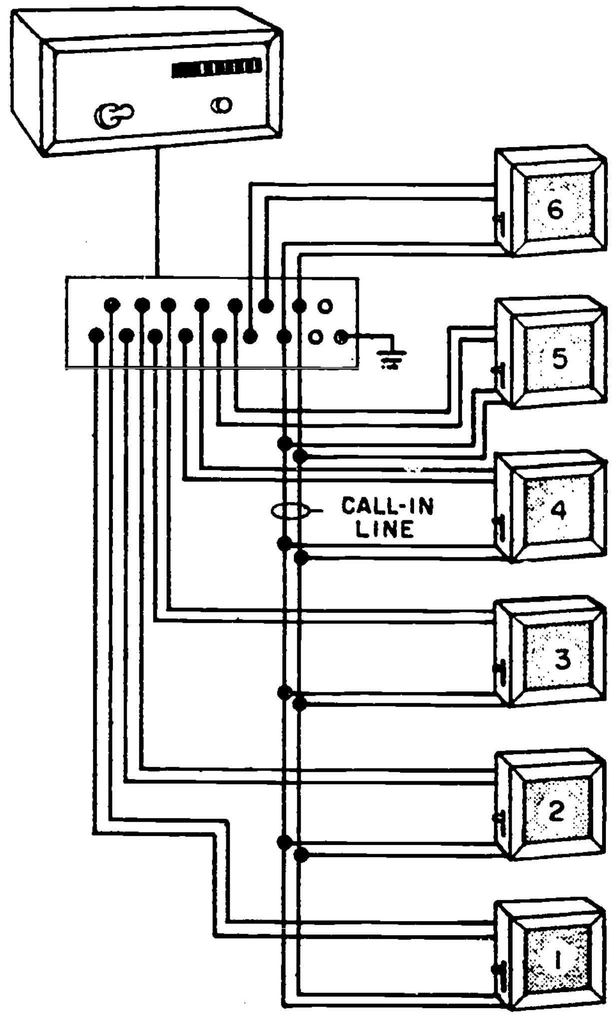
The switch panel consists of the selector switches (6 for the model shown), a space above each switch for identifying the station, and an annunciator for each switch. (All intercoms are not equipped with annunciators.) The switches have three positions: OFF, ON, and a third position to operate annunciators on a remote annunciator's master station unit.

The annunciators are solenoid plungers mounted above each station selector switch. When the button atop a remote speaker-microphone is depressed, or when a switch on a remote master unit is pressed down, a buzzer at the master station sounds, and the annunciator above the switch for the calling station springs outward. The annunciator remains out until the operator pushes it in; it should be pushed back to its normal position at the same time that the selector key is raised to answer the call.

The talk-listen lever is a 3-position switch. The three positions are IDLE, LISTEN, and TALK. Under normal operating conditions, the lever should be left in the idle position. The idle position should be used to determine whether a station to be called is in communication with another station. Leaving the lever in the idle position, flip the selector switch of the station that is to be called. If no other station is conversing with this station, press the lever to the talking position and speak into the master station. If the system has only one master unit, you may press the lever into the talk position without going through the idle position, since remote speaker microphone units cannot communicate with one another.

INSTALLATION PROCEDURES

Any combination of master stations and speaker microphone units up to the capacity of the master station can be used. Where it is not necessary for remote stations to communicate among themselves, only one master station will be installed; this is the usual case. (Figure 12-51 shows a circuit with all remote speakers connected to call-in line.)



26.131

Figure 12-51.—Six-station intercom system layout.

Install the master station within reach of a 110-125 volt, 50-60 hertz a-c power outlet. The master station and the speaker microphone units should be placed on the desks or in the working spaces of the personnel who will use them. If some of the units are installed outdoors, take the necessary precautions to protect them from adverse weather conditions.

The size of the wires to be used in making connections between units is governed by the length of wire. For the voice lines, No. 22 to No. 19 twisted pair wire is used. The maximum wire resistance permissible will be stated in the operating instructions. For the model shown the maximum resistance is 50 ohms per pair. The amount of wire determines the wire size to be used. No. 22 wire gives a resistance of 32 ohms per 1000 feet, and No. 14 wire gives a resistance of 4 ohms per 1000 feet. The larger sizes of wire (lower number) should be used when long lengths are necessary to connect the units.

The wire resistance of the annunciator lines must be kept below 15 ohms per pair. Normally, No. 14 or No. 16 wire is used.

All connections to a master station unit are made on the junction box. Be sure that the interstation wires do not cross hot pipes. The wires should never be placed where they are in danger of being covered by water.

After the wiring is installed, check the resistance with an ohmmeter. Make certain that the maximum permissible resistance is not exceeded and that there are no opens, grounds, or shorts. (Note: Follow installation instructions that come with each new set.)

TROUBLESHOOTING

Many of the troubleshooting instructions that apply to switchboards apply equally to intercom systems. In general, troubleshooting techniques consist of five steps:

1. Look
2. Feel
3. Tighten
4. Clean
5. Adjust

The first step consists of looking for such items as unlit tubes, frayed or broken wires, broken component connections, and dirt.

The feel operation is necessary to check and determine if electrical components are overheated. Be certain that the power is disconnected before performing this operation.

The tightening, cleaning, and adjusting operations are self-explanatory.

Components in intercom sets are readily accessible and may be easily replaced if found to be faulty. When a defective component such as a burned-out resistor or transformer is located, remember that the cause of the condition may be in some other part of the circuit. If the cause is not located and corrected, the new part will be burned out in the same way as the one that was replaced.

When trouble develops in an intercom system which has been properly installed and has been operating properly, the fault will usually be in one of the units of the system rather than in the interstation wiring. If the fault is in the interstation wiring it can easily be traced because the units will usually operate properly on some branches of the system. Once a fault has been traced to some particular unit it can sometimes be located by sight or smell (burned-out resistors and shorted transformer) but most faults must be traced by checking voltages and resistances.

In troubleshooting ALWAYS REMEMBER:

1. Noise or hum may be mechanical noises picked up by the microphone and amplified at the master station; or it may be caused by office equipment, or other external causes.

2. The majority of master station trouble can be traced to faulty tubes. Replace the tube with a set of tubes known to be good before becoming involved in major troubleshooting procedures.

Before parts are unsoldered the position of the leads should be noted. If the part has several connections to it, each lead should be tagged. Care should be taken that other leads are not damaged by being pulled or pushed out of the way.

Remember the following facts when you are soldering connections:

1. A carelessly soldered connection may create a new fault.

2. A poorly soldered joint is a very difficult fault to locate.

3. Don't allow drops of solder to fall into the set as they may cause a short circuit.

These points should be remembered particularly when leads are being soldered on intercoms. This information however, applies to soldering of all communications equipment.

PUBLIC ADDRESS SYSTEMS

During the early stages of an invasion, portable types of public-address systems are in extensive use for making amplified-voice announcements in the landing area. Small types of PA systems are d-c battery powered and completely self-contained. For strong sound coverage required to overcome a high level of noise in the area, a large a-c portable PA system, powered by a gasoline engine-driven generator, is used.

At an established base a PA system may be used for the auditorium, for outdoor movies, and for camp-wide announcements. The system generally used is a portable set consisting of a 100-watt cabinet-type amplifier, a dynamic (movable coil) microphone with heavy-duty floor stand, two 25-ft lengths of shielded microphone cable, and one 25-ft length of heavy-duty power cable. The system requires a 100/125 volt, 50/60 hertz power source.

The horns used as loudspeakers can be controlled individually or in any combination. The speaker can address a single station, several stations, or all stations. A changeover switch is provided to allow signal input from either a microphone or a phonograph.

As with any electrical circuit, the wiring diagram provides the key for the proper wiring connections. Normally, No. 14 size wire should be used for wiring connections. Horn loudspeakers may be mounted on buildings, poles, speaker stands, or even in trees. In selecting a permanent location for a loudspeaker, you should test for uniform loudness, minimum echo, and the possibility of an acoustical dead spot.

When installing a PA system, make sure you follow the manufacturer's instructions carefully.

COMMUNICATIONS MAINTENANCE AND REPAIR

The best possible equipment develops occasional faults in service. Also, the addition of new circuits, the placing of cross connections, the installation of local switchboards, and similar changes and rearrangements may be required. It follows that maintenance means more than just cleaning and lubricating. Besides what has been suggested, maintenance includes preventive maintenance — that is, a set routine of periodical tests, checks, and inspections, designed to head off trouble before it develops to the extent that it causes damage.

BATTERY MAINTENANCE

Inspect containers regularly for dirt, dust, or cracks. Clean them with a dry cloth, never with a damp or wet cloth.

Examine the terminals and the straps between the cells for looseness or corrosion. If terminals need tightening, do not use excessive force because it may damage the connections. Remove corrosion with sandpaper or crocus cloth.

Check the electrolyte for level and for specific gravity. The level should be at the upper red line on the jar. To check specific gravity you use a pilot cell. Use a new cell after every 50 readings.

For telephone storage batteries the voltage should be at least 46 but not more than 52 volts if the batteries are charged during use. Violent gassing and temperature rise in the electrolyte indicate that the charging current is too high.

Guard against fire hazards at or in the vicinity of batteries. Loose connections can be very dangerous because of the possibility of sparking. AT ALL TIMES keep open flame, lit tobacco, or any other type of fire, however small, away from batteries.

CIRCUIT TESTING

All circuits should be tested at regular intervals. When you know a fault exists, the wiring diagram is an invaluable aid in helping you to pinpoint the location. If you cannot find a broken wire, faulty connection, or other fault available to casual inspection, you will have to locate the trouble by continuity, voltage, and resistance measurements. Start at a point where the circuit is known to be good (up to that point), and isolate parts beyond, step-by-step, until you have located the fault.

WIRING MAINTENANCE

Most of the maintenance on wiring will be corrective rather than preventive — that is, it will consist of the location and correction of faults which have become evident. However, you will inspect terminal boxes for broken lugs and defective faceplates; and you will check drop wires for adequate support, connections, and insulation. Most of your maintenance on wiring, however, will consist of locating and correcting opens, grounds, and shorts.

If the signal lamp on a switchboard lights continuously, a ground is indicated. Check the ring line (or tracer wire) first. Place the receiver of your test telephone in series with the tracer line at the nearest terminal box. If you hear a sharp click, move to apoint nearer the defective telephone. When you hear no click, the ground is between the point where you then are and the last point where you heard a click.

If the ground is in the plain conductor or tip line, there will be a noise on the circuit, caused by ground returns of other currents. Disconnect the tip line from its terminal at the pole, and then attach your test receiver leads to the ring line and to the part of the tip line that leads to the defective telephone. A click indicates that the ground is between you and the subset. Keep moving toward the subset until you fail to get a click. This indicates that the ground is between the point where you are now located and the last point where you received a click.

The diagrams in figure 12-52 illustrate the method of testing a ring line and a tip line for ground.

To locate an open circuit in one of the pairs of wires, start at the terminal box which is closest to the central office, and which has terminals tapped to the pair of wires to be tested. Connect the leads of your test telephone across the proper terminals. One lead should be clamped on, the other just tamped against the terminal. If you fail to receive a sharp click, one line in the overhead cable is dead, and will require splicing at the open. You may hear a very faint click, but this will be caused probably by a difference in ground potentials and not by battery voltage.

If you hear a sharp, definite click, you can be assured that battery voltage is present up to that point—meaning that there is no open in the line up to that point. The next point of testing will have to be the terminal box to which the drop wire is connected. A sharp click at this point indicates that the open is in the drop wire or the inside wiring.

The dividing point between drop wire and inside wire is the protector, so make that the next testing point. If no click is received when you place the test leads across the protector,

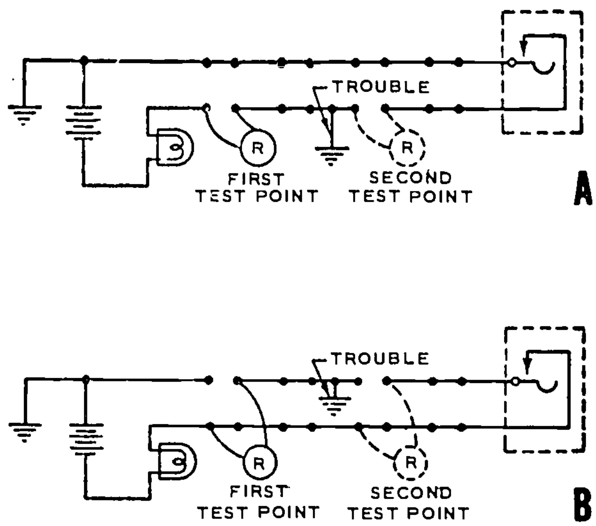


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Figure 12-52.—Testing for ground. (A) Ring line; (B) Tip line.

the open is probably in the drop wire. Perhaps an inspection will indicate the break, and you can splice the wire. Otherwise you may have to replace the entire drop wire.

To determine if the ground line at the protector has an open, use your test telephone leads where the pair of wires comes into the protector, by attaching one lead to the ring line, and tapping the tip line with the other lead. If you receive a click, tap the ground line (instead of the tip line) with the second lead. A click indicates that the circuit is good to ground. Absence of the click indicates an open.

To locate a short, go to the first check point and place your test receiver in series with the tip line. A click indicates that you are between the short and the central office, so keep working along the drop line until you fail to receive a click. At that point, you are beyond the short, so you know it lies between the last two points that you tested.

SUBSET MAINTENANCE

The first step in checking a subset is to identify the cause of the trouble. It may be only a loose connection, or the presence of some foreign material or iron filings around the ringer magnet.

You should know the number and location of the subset, the cable pair number, the location and number of the cable terminals, and the location and number of the cross-connecting box, if any. Examination of any previous trouble reports is helpful, because previous troubles may suggest the nature of present troubles.

Subset troubles may usually be broadly divided into those that lie between the central office and the subset and those that lie in the subset itself. For those between central office and subset a good point of beginning is the main distributing frame. This is the dividing point between outside plant and inside plant, and also the point of location of the central office protective devices.

Check the protector (where drop wire connects with inside wire); look for moisture; check for broken, defective, or loose fuses; replace badly pitted carbon blocks; check the ground wire.

At the subset, examine the transmitter for cracks or breaks in the mouthpiece; for missing rim screws or loose contact springs; and for dirt or moisture. Look inside the receiver for dirt, corrosion, moisture, or cracks. Examine the mounting of the ringer, and look for dents or cracks in the coils. Observe the contact and lever action of the hook switches, and look for rusty, bent, or pitted springs. Check to see that stay cords and hooks are secure.

The main thing is to put the line back into service as soon as possible, so for considerable repair, replace the subset and send the defective one back to the shop.

SWITCHBOARD MAINTENANCE

Inspection, tightening, cleaning, and adjusting are the basic operations in switchboard maintenance. Periodic inspections are of the utmost importance, because a minor defect may not interfere at once with the performance of the equipment, but may lead in time to a major breakdown. Keep all food and beverages away from the switchboard.

Every day the switchboard exterior should be wiped off with a soft, dry cloth. The batteries, headset, chestset, and exterior of the distribution frame should be inspected. Chipped paint, mildew, and corrosion must be removed, and the storage batteries must be checked for electrolyte level. Do not forget to inspect the wiring on the rear of the panel.

Weekly inspection should be given to cords, keys, shutters, fuses, protector blocks, heat coils, repeating coils, and ground rods.

Inspect the cords for dirt, dust, or fungus. Check the cord weights and pulleys for smooth operation. Wipe the cords with a clean, dry cloth.

Use long-nosed pliers to adjust the drop shutter latches. Then test to see if the shutters fall freely when a call is received, but remain in place when the switchboard is jarred.

Ascertain that fuses are of the proper capacity, and tighten the fuse mounting screws.

Remove dust, dirt, or other foreign matter from the protector blocks, and replace porcelain or carbon blocks that are chipped or broken. Use care in cleaning, because if you dislodge a block you can cause trouble on an incoming line.

Inspect heat coils for cleanliness, and replace any that show chipped or broken coils. Do not remove the covers of repeating coils, but examine the mountings for loose, damaged, or missing screws. Clean the coils with a dry, clean cloth.

Look for rust or corrosion on ground rods. Check to make sure that the wing bolt at the terminal connection is tight.

Plugs, relays, capacitors, terminals, binding posts, and cables should be given monthly inspection. Clean the switchboard plugs with cord plug polish, using a clean, dry cloth. Remove all residue of the polish after cleaning in order to maintain good electrical contact.

Inspect relays and capacitors for dirt and foreign matter, and clean with a dry cloth.

Inspect terminals and binding posts on the switchboard for cleanliness and tightness of connections. Check incoming line connections for good electrical contact. Tighten any loose terminals with a suitable screwdriver or wrench.

Clean the terminals and binding posts with a soft bristle brush.

Examine connecting cables for damaged or worn insulation. Check the fittings on the ends of the cables for tightness and good electrical connection. Tighten the connections on the cables as required.

INTERCOM SYSTEM MAINTENANCE

In general, the four basic steps in switchboard maintenance — inspect, tighten, clean, and adjust — apply to intercom system maintenance as well, with inspection being always of primary importance.

The components in an intercom set are all readily accessible, and for the most part they can easily be replaced when they are found to be faulty. However, you must have enough knowledge of the working principles of the system to be sure that the defective part is the cause of, and not a result of, trouble in the system.

For example, suppose you find a burned-out transformer or resistor. You replace it, and the replacement burns out. Actually, the burned-out part was not the cause of the trouble, but a result of it.

PUBLIC ADDRESS SYSTEM MAINTENANCE

Trouble in a PA system is often caused by nothing more obscure or complex than a loose cable connection or a break in the cable shield. Check for simple faults of this type before you begin a lengthy system of tests.

In soldering connections, make certain that both metals are absolutely clean, and that the completed soldering job is firm and durable. Faulty soldering in a PA system can cause defects which are very difficult to identify and locate. Too much solder can cause shorts in microphone connectors that may not be visible to the eye.

The identification and location of serious troubles in the system may require the use of signal tracing equipment, such as an audio-signal generator, an output meter, or an oscilloscope. In testing the electric circuit, the most important point to remember is that the trouble should be pinpointed as to location. A careful study of the circuit diagram is essential.

TOOLS AND EQUIPMENT

Tools and equipment required for maintenance and repair are included as part of a field telephone set component. For subsets taken out and sent to the shop for repair, the maintenance tool is the same test telephone which you use in locating shorts, opens, or grounds.

In general, you should have the following tools, equipment, and materials available when you begin any cleaning, adjustment, or repair process:

Test telephone
Clean, dry cloths and soft bristle brushes
A drycleaning solvent
Cord polish
Crocus cloth or No. 000 sandpaper
Screwdriver set
Long-nosed pliers
Wrench sets, both open and socket
Battery hydrometer

CHAPTER 13

TELEPHONE CABLE SPLICING

Telephone cable splicing is an important function of the CE's job. This chapter provides information that will aid you in splicing telephone cable safely, economically, and efficiently.

The knowledge you acquire in this chapter regarding cable terminology, types of cable, and the procedures for splicing a variety of cables will enable you to render vital services in the communication link.

Most lines, whether for telephone or for power distribution, require some splicing. The length of cable on a reel seldom equals exactly the length to be installed. Even after a system has been installed, there will always be a certain amount of splicing necessary, to take care of repairs on defective cable sections, or to add extra sections to the main cable.

Whenever splicing is required, remember that you are playing a vital role in keeping communication lines operating properly.

TELEPHONE CABLE CLASSIFICATION

There are four types of telephone cables: lead-covered, tape-armored, building and switchboard (silk and cotton), and plastic-covered (polyethylene) cable. For many years, lead-covered cable was used more than the other types. However, plastic-covered cable is now being used more than the lead-sheathed type for two reasons: plastic cable is cheaper to produce than lead, and it also has the advantage of being lighter in weight than the lead-sheathed type. You can expect to be working much of the time with plastic-covered cable, and in some cases you will be replacing existing lead-covered cable with plastic-covered cable. Two considerations will determine the selection of the type of cable to be used: the job it will perform and the kind of environment into which it will be placed.

There are four types of cable installations: aerial, direct-burial, underground and submarine. Aerial installation is aboveground, and most of your experience will be with this type. When cable is buried directly in the ground without conduit, you have a direct-burial installation. In an underground installation, the cable is installed underground in conduits. Sometimes cable must be installed in submarine areas; that is, under water or in swampy areas.

The following paragraphs tell about the different kinds of cable, how they are used, and how they are installed.

LEAD-COVERED CABLE

Lead-covered cable is insulated with paper. The insulation may be sprayed on as a pulp, or the paper may be wrapped spirally around the conductors. Double-wrapping of wires provides a highly dielectric (non-conducting) insulation, both because of the additional thickness of the paper and because of the additional air space. This higher insulation protects against insulation breakdown which might occur if a telephone line came into contact with a powerline. Lead-sheathed cable is used for installations underground in conduits.

TAPE-ARMORED CABLE

Tape-armored cable is a lead-covered cable fitted with a protective covering of paper, jute, and steel tape. This covering protects the cable against damage by rodents and against mechanical damage. It is used for direct burial (placed underground without conduit) and also for submarine installation; that is, in swampy land or water.

Tape-armored cable is quadded, colored-coded, and composite. In quadded cable, some or all of the conductors are arranged in quads, or groups of two pairs. A cable containing 26 or more pairs of conductors is color-coded according to groups, to simplify matching for splicing. Composite means that the cable contains conductors of two or more sizes.

BUILDING AND SWITCHBOARD CABLE

Building cable is made up of copper conductors covered with weatherproofed neoprene jacket insulation. It is used to make connection from telephone poles to buildings.

Switchboard cable is made up of copper, or tinned copper, conductors with a silk and cotton insulation; but it is also available with black enamel insulation. Pairs of conductors are usually bound together with a spiral layer of paper, a layer of lead tape, another layer of paper, and a fireproofed braid. The insulation is colored according to a standard color scheme, so that each pair of wires and each unpaired single wire can be identified. Switchboard cable is used to connect the switchboard apparatus to the main distribution frame. It may also be used for local wiring in the switchboard. On newer installations, the switchboard cables, or jumper wires, will probably be No. 22 copper conductors with a plastic insulating jacket. This wire ordinarily comes on 1000-foot spools and is used primarily for making connections on the main distribution frame.

PLASTIC-COVERED CABLE

Polyethylene or plastic-covered cable has solid copper conductors, each with polyethylene insulation. It is used in aerial installation; that is, suspended on poles, and for direct burial underground without conduit.

SPLICING TELEPHONE CABLE

The three most commonly used types of telephone cable splices are the straight splice, the bridge (sometimes called branch) splice, and the butt splice. These three types are illustrated in figure 13-1. In view A of figure 13-1 the cables come from opposite directions, the splice in each individual wire being covered by a small cotton sleeve. In view C, the wires enter the sleeves from the same direction. In view B, however, two cables coming from one direction have been spliced to a single cable coming from the opposite direction.

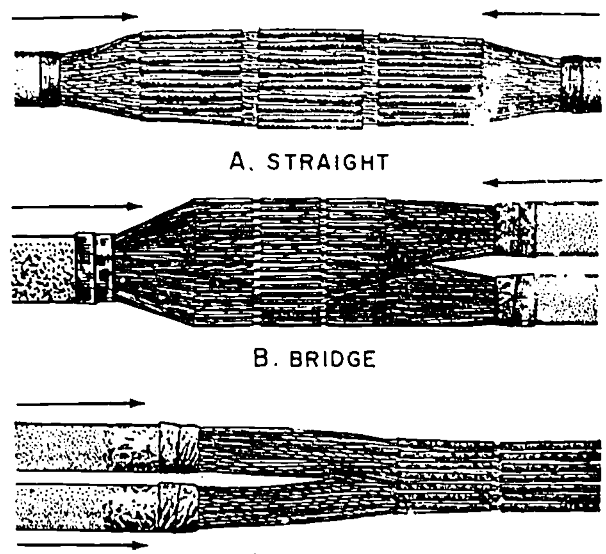

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Figure 13-1.—Types of telephone cable splices.

Straight splicing is the simplest method of splicing, consisting as it does of joining two wires that approach the splice point from opposite directions. Most of the splicing that you do will be by the straight splicing method. Bridge splicing usually consists of splicing a branch into a main cable. Butt splicing is usually done to attain flexibility; a butt splice is often later changed to a straight or bridge splice.

SPLICING LEAD-SHEATHED CABLE

While most of the splices that you make in lead-sheathed cable will be straight splices, you will also on occasion make bridge and butt splices in this cable. The procedure below applies to all three types of splices. The steps of the procedure are as follows:

1. Mounting the sleeve.
2. Removing the sheath from each cable end.
3. Drying out the insulation by boiling out or by using a desiccant.
4. Identifying and selecting the correct individual wires from each cable.

5. Splicing the wires in a staggered pattern.

6. Placing and wiping the sleeve.

The following sections explain each of these steps in detail.

Mounting Sleeve

The size of the lead sleeve will depend on the size of the cable, the diameters and number of wires, and the type of splice. The splice on a pair of individual wires is covered with a small diameter cotton or plastic sleeve. The size of the cotton or plastic sleeve depends on the diameter of the spliced wires it covers. The whole splice—that is, the bundle of spliced individual wires—is covered with a larger diameter lead sleeve.

It is advisable to slide the lead sleeve onto one of the cables as soon as the ends have been arranged and prior to the preparing and removal of the lead sheath. Slip the sleeve up the cable far enough to have it out of your way as you perform the individual wire splicing operations. When all the wire splices have been completed, you can draw the sleeve down over the bundle.

Before you slide the lead sleeve on, inspect it for cleanliness and for sharp edges. If necessary, smooth up the ends with a lead file.

Removing the Sheath

Measure the length of the sheath to be removed, and ring the cable at the point where the cut is to be made. The diagram in figure 13-2 shows a distance of 18 inches, but this is only by way of illustration. In every case the length of the splice opening will depend on (1) the size of the cable (in terms of the number of pairs of wires), (2) the diameters of the conductors, and (3) the type of splice being made.

In ringing cable be sure, as with power cable, that the cut or score does not penetrate completely through the sheath. A too-deep cut may damage the conductors, whereas a properly shallow cut bells the sheath, as desired, when the section to be removed is pulled off.

Clean the sheath back from the ringed point (distance AB in fig. 13-2). On new cable use a file as a cleaner. On old cable a shave hook is better. If dull or dark streaks are left they

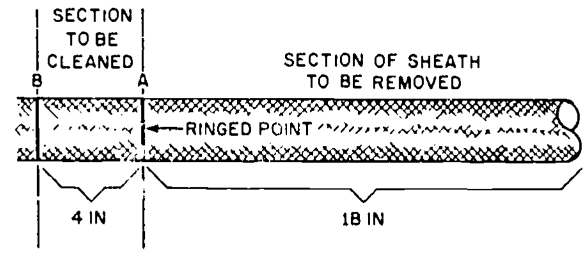

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Figure 13-2. — Preparing cable for splicing.

will not tin properly when the joint is wiped later, and the joint will be defective.

Immediately upon cleaning this area, and before your hands have touched it, coat it with stearine, and wrap it with a double layer of boiled-out muslin. This is to protect the area while you are removing the adjacent length of sheath for the splice opening.

You split the sheath with a splitting knife (also called a chipping knife) as described for power-cable splicing in chapter 11. You must avoid cutting through the paper wrapping of the cable core, so be careful in driving the knife under the edge of the split to loosen the sheath.

Grasp the cable at the section where you wrapped it in the protecting layer of muslin, and gradually work off the split portion of the sheath. It should break off at the ringed point. Figure 13-3 shows the main steps in removing the sheath.

When the sheath has been broken off, inspect the broken-off edges on the cable ends to ensure that they are smooth. Any sharp edges or burrs could cause damage to the conductor insulation during splicing. The best way to guard against this is to butt the sheath edges with boiled sleeving muslin, or cotton tape, as shown in figure 13-4.

Boiling Out Insulation

"Boiling out" is a term used to refer to a procedure for removing any moisture which may be present in the insulation. Besides removing moisture and preventing the same from reentering the break, boiling out makes it easier for you to remove the paper insulation from individual wires en you are ready to splice them.

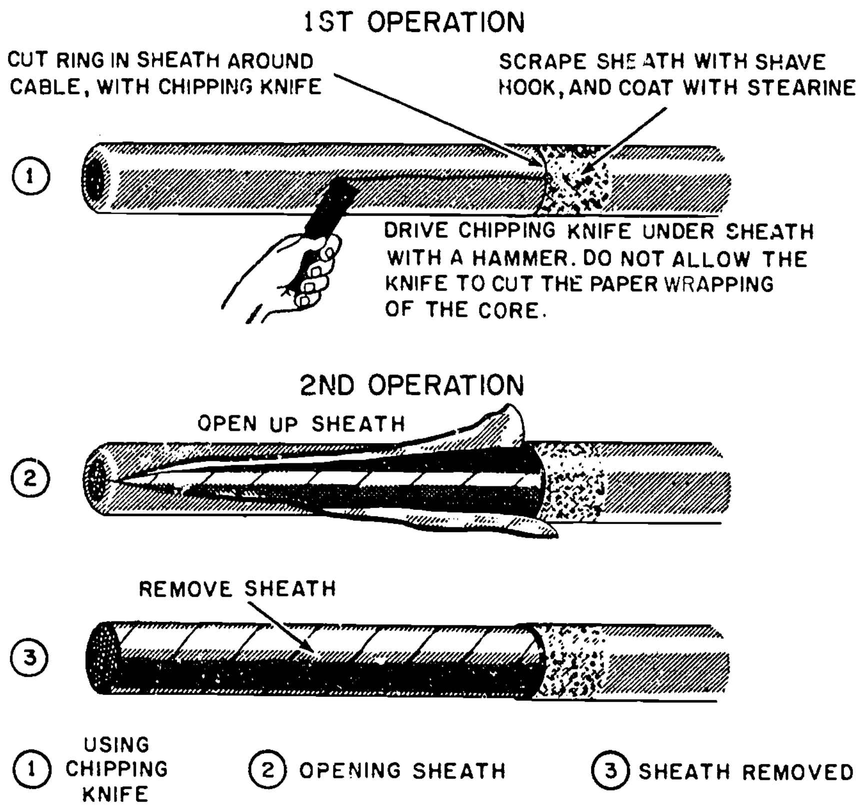

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Figure 13-3. — Steps in removing sheath.

Boiling out consists of pouring hot paraffin over the sheath, starting about 6 inches back from the exposed wires, and gradually working the stream of paraffin onto the paper insulation and out to the ends of the wires. The temperature of the paraffin should not exceed 375° F — temperature higher than 390° F will damage the paper insulation. If you do not have a thermometer capable of registering such high temperature, you can apply a practical test to the paraffin when it is heating. Watch the dry ring that forms and gradually creeps up on the outside of the pot. This ring will begin to form when the paraffin is at about 360° F. When the ring is about 2 inches wide, the paraffin is at the correct working temperature.

The paraffin, as it cools and hardens, forms a seal which excludes the entrance of moisture. When you are splicing large cable, it is advisable to repeat boiling out as soon as you have spliced 200 pairs of wires. The reason is that by the time you have spliced 200 pairs of wires the insulation will have begin to absorb moisture from your hands and from the atmosphere. Another boiling out will remove this moisture and reseal the insulation.

If the splice is left incomplete overnight, or if you are working in a very damp atmosphere, you may have to go through the boiling-out process several times. Discoloration of the insulation or a bluish-green discoloration of the conductors are sure signs that excessive moisture is present. If discoloration is present, boil out again.

Drying By Desiccant

The paraffin boiling-out method of drying has several disadvantages. These include fire hazard, objectionable fumes, possible burns to personnel, and splashes of hot wax on floors or walls. The

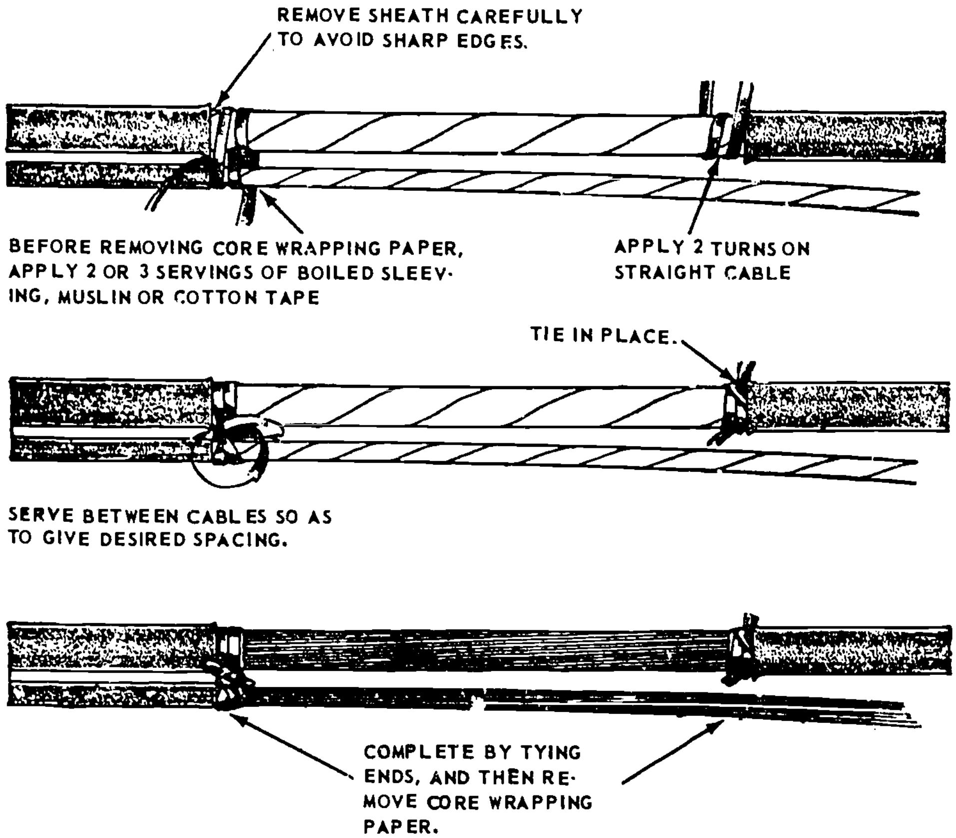

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Figure 13-4.—Butting the sheath.

method of drying by the use of a desiccant (drying agent) is therefore often used instead. The usual desiccants employed are anhydrous calcium sulfate and silica gel. A desiccant absorbs moisture whereas hot paraffin drives it out.

A desiccant is used after the splicing and sleeving are completed. The splice bundle is enclosed in a muslin envelope long enough to overlap at both ends of the splice. Open one end of this envelope and let the desiccant trickle in all over the conductors. Spread the wires apart with your fingers to allow good penetration.

Conductor Identification

Conductor identification is predicated upon the establishment of a pair count. This operation is indispensable to the proper testing and splicing of telephone cable. Three considerations are involved in the count: the relative position of cable and central office, geometric pattern, and tracer pairs.

POSITION OF CABLE AND CENTRAL OFFICE.—The first consideration in the establishment of the count is the relative position of the central office and the cable end to be spliced. If the exposed end faces away from the central office, the count is made in a counterclockwise direction. If the exposed end faces toward the central office, the count is made in a clockwise direction (fig. 13-5).

GEOMETRIC PATTERN.—Cable may contain various quantities and combinations of geometric patterns (fig. 13-6). The count begins at the center of the core and proceeds to the sheath in a clockwise or counterclockwise direction.

As an aid in establishing or determining identification of pairs, the cable cores are color

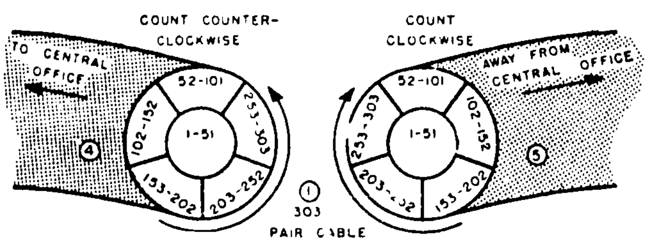

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Figure 13-5.—Cable conductor groups, 303 pair cable.

size cables, except those smaller than 25 pairs, can be divided by this number. The pairs within the 25-pair groups are identified by a simple code that uses 10 colors, 5 for tip and 5 for ring, with no duplication. The 25-pair groups (table 13-1) are bound with bicolor binders which follow the 5 + 5 color code used for pairs.

TRACER PAIRS.—The core of non-polyethylene insulated cable contains certain distinctively colored conductors known as tracers. A tracer pair is used by the splicer to establish a talking pair to his helper at the distant end

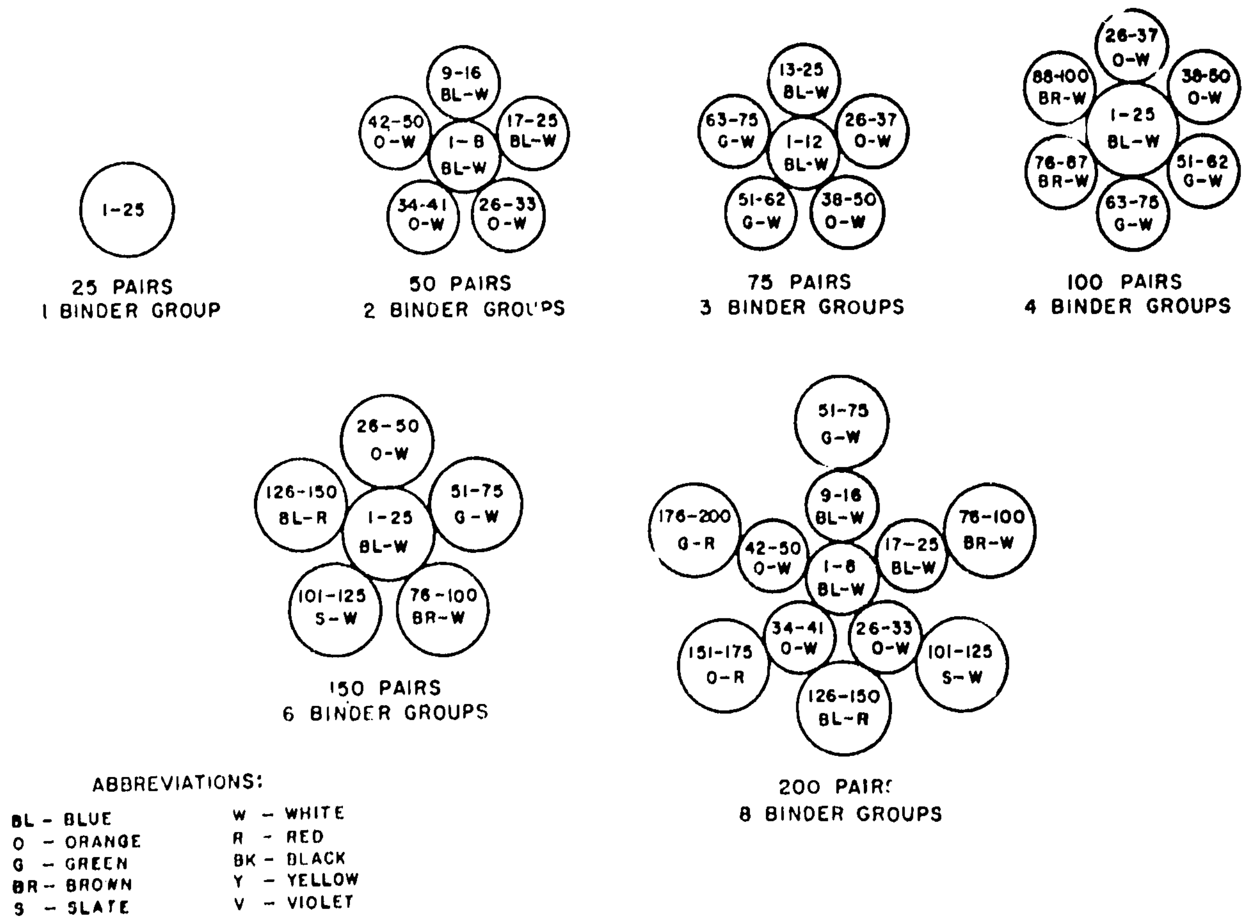

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Figure 13-6.—Core makeup of one type of cable.

coded by layers or groups bound separately by colored, spirally wrapped, soft textile binders or markers.

A group of 25 pairs is considered as the most suitable size for a uniform group, and all standard of a length of cable being spliced at a terminal or at the main distribution frame in a central office. Terminated tracers are connected to the highest number terminal for that cable or group. A 101-pair terminal would have the tracer

Table 13-1.—Binder Marking for 25 Pair Groups

Group No.	Color of Bindings	Group Pair Count
1	White-Blue	1 - 25
2	White-Orange	26 - 50
3	White-Green	51 - 75
4	White-Brown	76 - 100
5	White-Slate	101 - 125
6	Red -Blue	126 - 150
7	Red -Orange	151 - 175
8	Red -Green	176 - 200
9	Red -Brown	201 - 225
10	Red -Slate	226 - 250
11	Black-Blue	251 - 275
12	Black-Orange	276 - 300
13	Black-Green	301 - 325
14	Black-Brown	326 - 350
15	Black-Slate	351 - 375
16	Yellow-Blue	376 - 400

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terminated on pair 101. When splicing non-color-coded cable, the conductor having red, green, or blue is the ring conductor and the white is the tip conductor.

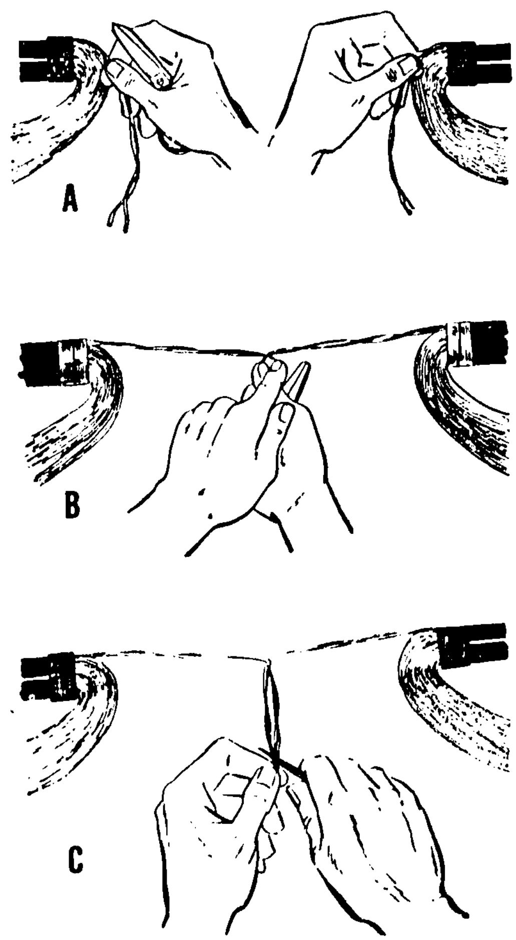

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Figure 13-7.—Joining a pair of wires.

Splicing the Wires

The pairs of wires are arranged within a cable in color groups, with low count at the center of the core and the higher count outside. The arrangement assists in quick identification. However, you should always work from a splicing diagram, or at least from definite identification instructions.

Lash the cable ends into convenient adjacent position, and fold the wires back as shown in figure 13-7, view A. Next, grasp a pair of wires from the right-hand cable end, the corresponding pair from the left-hand end, and give them a half-turn as shown in figure 13-7, view B. Then, holding both pairs of wires in one hand, cut them about 4 to 4 1/2 inches from the turn, as shown in figure 13-7, view C.

Before the splice can be made, the insulation must be stripped from the lengths of wires beyond the turn. As shown in figure 13-8, you grasp the wires just below the turn and pull the insulation off the ends. It is best to pull away from the turn and slightly toward the side on which you plan to slip the cotton sleeve. This will prevent the ends of the wires from curling.

Next you fit cotton sleeves onto both wires at the same time, slipping them over the wires. Use a rotating motion to slide the sleeves up to a position where they will not interfere with the splicing procedure.

Now bend one wire of each pair back out of the way and draw the other wires of each pair together as shown in figure 13-9. Draw the wires close together, so that the splicing twist can be

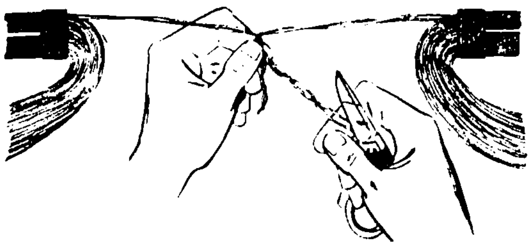

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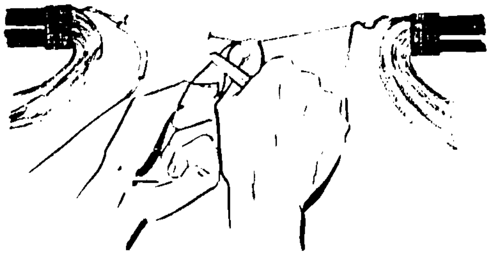
Figure 13-8. –Stripping insulation from wires.



73.198
Figure 13-9. —Drawing wires together for splicing.

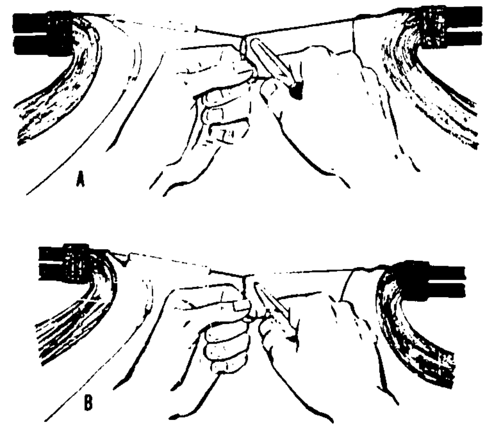
made close to the ends of the insulation. Then make the crank-handle twist shown in figure 13-10. First roll the left-hand wire over the right-hand one. Then bend them at right angles, and twist them together with a cranking motion of your wrist, until you get a twist about 1/2 inch long.

Bend or twist the pigtail, and cut off the excess wire. Then slip the sleeve down over the joint, as shown in figure 13-11.

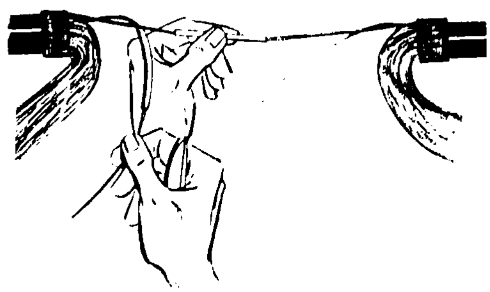
It is, of course, vitally important that you know what wires go together. However, it is always possible that you may have to do an emergency job where you don't have the necessary information in advance. In a case of this kind, a knowledge of the arrangement of groups in a cable will be of great value.

Placing and Wiping the Sleeve

After you have spliced all the pairs of conductors, wrap the splice bundle with two layers of



73.199
Figure 13-10. — Twisting the wires.

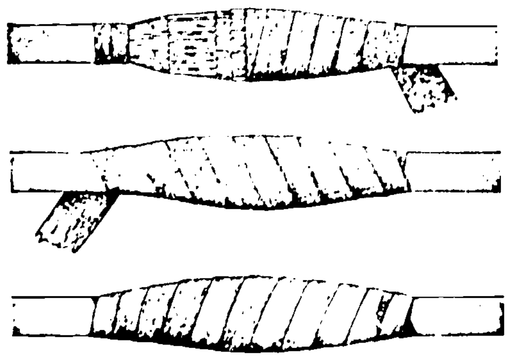


3.200
Figure 13-11.—Slipping the sleeve over the splice.

dry muslin, as shown in figure 13-12. Slide the lead sleeve into place, exercising care to protect the cotton sleeves on the individual wire splices as well as the muslin wrap. This will prevent the wires from coming into contact with one another or with the lead sleeve.

Unless you made your individual splices neatly and compactly, and unless you staggered them so they don't bunch up all at the same point, you will have difficulty getting the sleeve over the splice bundle.

The procedure for wiping the lead sleeve is the same as that described for a sleeve on a power cable in chapter 11.



73.202
Figure 13-12.—Wrapping the splice.

SPLICING SILK AND COTTON INSULATED CABLE

Paper ribbon or paper pulp insulation has certain disadvantages which make it unsuitable for use on cables to be connected to distribution frames, terminal strips, and other interior terminal points. The reason is that the paper insulation is not strong enough to withstand the amount of handling required to make connections. In working the core into a form which is fanned out and laced, the paper insulation, which is not baked on, will unroll. Besides, paper insulation deteriorates on exposure to air, and its dielectric strength falls off considerably on exposure to moisture.

It is the custom, therefore, to splice incoming paper-insulated cable onto short lengths of lead-covered textile-insulated (silk or cotton insulated) cables called cable heads. The heads are used to make the direct connections with central office distribution frames and terminal strips.

Prepare silk and cotton insulated cable for splicing by boiling out with beeswax, or with a special petroleum wax. Do not use paraffin, because it discolors the textile insulation, and makes it very difficult for the operator to separate conductors for fanning, forming, and splicing. On the other hand, do not use beeswax on paper-wrapped insulation, because it will make the paper brittle and may cause breakage.

Start pouring the wax a few inches back on the sheath, and gradually advance toward the exposed conductors. To start at the conductors and go the other way would defeat the purpose of boiling out by forcing any moisture under the sheath further back.

The same standard splice openings, number of cotton sleeve banks, and splicing procedures apply to textile-insulated change cables as apply to paper-insulated exchange cables. When splicing silk and cotton insulated cable to paper-wrapped insulated cable, use a desiccant for drying out the joint.

Mark the point for removal of textile insulation by the same procedure described for paper-insulated cables. Cut off the conductors 4 1/2 inches from the end and use long-nosed pliers to crush the silk/cotton insulation at the marked point. Don't apply too much pressure, because this will flatten the conductor and may cuase it to break after splicing. After the insulation has been crushed, it can be removed by decreasing the pressure on the pliers and skinning the insulation off by pulling toward the end in a straight line. However, if you prefer you can pull it off with the fingers. Never use the back of the splicing scissors to remove insulation; this might break the relatively brittle tinned-copper conductors in a textile-insulated cable.

Some textile-insulated cables have enameled conductors, and this enamel must be thoroughly removed before the wires can be spliced. One method is by light scraping between the jaws of long-nosed pliers—but you must be extremely careful not to nick or flatten the wires.

A good tool for scraping enamel is the wire scraper, which consists of a steel spring 3/4 inch wide, bent in the form of a U and with ends turned and sharpened. As you gain skill with this tool, you will find it effective for removing silk, cotton, of plastic insulation.

Twist the conductors by using the same twist described for splicing paper-insulated cable. After the splice is completed, boil out with hot paraffin or dry with desiccant as you would a paper-insulated splice.

SPLICING POLYETHYLENE-INSULATED CABLE

Polyethylene-insulated cable (PIC) (polyethylene is commonly called plastic) is available as aerial or as direct burial cable, both types being made in even-numbered pairs. The cores of both types are identical, in that they are fully coded—meaning that each pair in the cable is distinguishable by color from every other pair. This is accomplished by the use of a color scheme which provides different colors of insulation for each pair in a 25-pair group, together with colored or imprinted bindings to distinguish 25-pair groups from each other. By referring to tables which give pair color codes, binder markings and possible layups, you can match the wires in one of these cables with little difficulty. See table 13-2.

PIC has solid copper conductors, each with polyethylene insulation of the required color. The insulated conductors are twisted into pairs. The required number of pairs are stranded into a cable core and enclosed in a metallic shield and polyethylene jacket or sheath.

In cables having 25 pairs or less, the twisted pairs are assembled to form a substantially cylindrical core. In cables having more than 25 pairs, the twisted pairs are arranged in groups, each group being bound by moisture-resistant thread or tape. Each group contains not more than 25 pairs. For layup purposes, the basic 25-pair groups may be divided into two or more subgroups called units.

Each unit in a particular 25-pair group is enclosed in bindings of the colors indicated for its particular 25-pair group. For example: suppose you have a 100-pair cable and are looking for pair number 88. You look for the group with binding colors white and brown; then look for the pair in that particular group with black and green insulation (see fig. 13-6 and table 13-3).

The aerial-type cable has an aluminum shield applied longitudinally over the core covering. The seam in this shield is joined during the manufacturing process by means of a cold weld, and electric weld, or soldering with a nonacid flux. A polyethylene jacket is then placed over the shield.

The direct-burial type cable has two polyethylene jackets with a copper shield between the inner and outer jacket. The inner jacket is placed over the completed core, and is from 50 to 70 mils thick according to the number of pairs in the cable. The outer jacket, placed over the shield, is from 40 to 80 mils thick.

SPLICING POLYETHYLENE CABLE FOR AERIAL INSTALLATION

The procedure for splicing polyethylene cable for use in aerial installation is described in following paragraphs. A point to note is that the main difference between a splice in polyethylene cable and one in other types of cable is in the method of enclosing the splice. A splice in polyethylene cable is enclosed in a polyethylene or neoprene enclosure unit consisting of a base assembly and a rubber or polyethylene cover which snaps in place over it, whereas a splice in other types is enclosed in a metal or plastic sleeve.

Removing the Sheath

The length of the opening in the cable sheath varies according to the type of closure and the size of the cable. Steps in removing the sheath are as follows:

1. After determining the length of the opening from the manufacturer's instructions, place three wraps of vinyl tape around the sheath at each end of the proposed opening to mark the ends, as shown in figure 13-13.

2. Ring the sheath carefully 3 inches from the splice opening marker tapes, as also shown in figure 13-13.

3. Remove the sheath between the two rings.

4. Remove the shield in the same area, as shown in figure 13-14.

5. Cut tabs in the jacket and shield in the 3-inch space between opening and marker tapes as shown in figure 13-15. Cut 3 tabs for cable up to 0.6 inch in diameter, 4 for cable from 0.6 to 1.6 inches in diameter, and 6 for cable from 1.6 to 2.2 inches in diameter.

6. Enlarge slot to 1/8 inch as also shown in figure 13-15.

7. Place two turns of vinyl tape, adhesive side out, then one turn with adhesive side in, as shown in figure 13-16. Push these wraps of tape under tabs as shown, to form a base for the clamps of the base assembly to be installed later.

8. Place two turns of vinyl tape to hold the core wrapper in place at the ends of the tabs, and remove the core wrapper.

Table 13-2.—Possible Layups of Polyethylene Insulated Cables With Standard Telephone Color Code

Size	Center			First Layer			Second Layer		
Pairs in Cable	Pairs in Unit	Binder Colors	Pair Count	Pairs in Unit	Binder Colors	Pair Count	Pairs in Unit	Binder Colors	Pair Count
50	8	White-Blue	1-8	9	White-Blue	9-17			
				8	White-Blue	18-25			
				8	White-Orange	26-33			
				9	White-Orange	34-42			
				8	White-Orange	43-50			
75	12	White-Blue	1-12	13	White-Blue	13-25			
				12	White-Orange	26-37			
				13	White-Orange	38-50			
				12	White-Green	51-62			
				13	White-Green	63-75			
100	25	White-Blue	1-25	12	White-Orange	26-37			
				13	White-Orange	38-50			
				12	White-Green	51-62			
				13	White-Green	63-75			
				12	White-Brown	76-87			
				13	White-Brown	88-100			
150	25	White-Blue	1-25	25	White-Orange	26-50			
				25	White-Green	51-75			
				25	White-Brown	76-100			
				25	White-Slate	101-125			
				25	Red-Blue	126-150			
200	8	White-Blue	1-8	9	White-Blue	9-17	25	White-Green	51-75
				8	White-Blue	18-25	25	White-Brown	76-1[illegible]
				8	White-Orange	26-33	25	White-Slate	101-12[illegible]
				9	White-Orange	34-42	25	Red-Blue	126-15[illegible]
				8	White-Orange	43-50	25	Red-Orange	[illegible]
							25	Red-Green	[illegible]
300	25	White-Blue	1-25	25	White-Brown	76-100			
	25	White-Orange	26-50	25	White-Slate	101-125			
	25	White-Green	51-75	25	Red-Blue	126-150			
				25	Red-Orange	151-175			
				25	Red-Green	176-200			
				25	Red-Brown	201-225			
				25	Red-Slate	226-250			
				25	Black-Blue	251-275			
				25	Black-Orange	276-300			
400	25	White-Blue	1-25	25	White-Orange	26-50	25	Red-Or[illegible]e	151-175
				25	White-Green	51-75	25	Red-Green	176-200
				25	White-Brown	76-100	25	Red-Brown	201-225
				25	White-Slate	101-125	25	Red-Slate	223-250
				25	Red-Blue	126-150	25	Black-Blue	251-275
							25	Black-Orange	276-300
							25	Black-Green	301-325
							25	Black-Brown	326-350
							25	Black-Slate	351-375
							25	Yellow-Blue	376-400

73.261

Table 13-3.—Color Code For Plastic-Insulated Conductor Cables

Pair No.	Group binder		Color of insulation Tip	Ring
1	Blue	White	White	Blue
2	Blue	White	White	Orange
3	Blue	White	White	Green
4	Blue	White	White	Brown
5	Blue	White	White	Slate
6	Blue	White	Red	Blue
7	Blue	White	Red	Orange
8	Blue	White	Red	Green
9	Blue	White	Red	Brown
10	Blue	White	Red	Slate
11	Blue	White	Black	Blue
12	Blue	White	Black	Orange
13	Blue	White	Black	Green
14	Blue	White	Black	Brown
15	Blue	White	Black	Slate
16	Blue	White	Yellow	Blue
17	Blue	White	Yellow	Orange
18	Blue	White	Yellow	Green
19	Blue	White	Yellow	Brown
20	Blue	White	Yellow	Slate
21	Blue	White	Violet	Blue
22	Blue	White	Violet	Orange
23	Blue	White	Violet	Green
24	Blue	White	Violet	Brown
25	Blue	White	Violet	Slate
26	Orange	White	White	Blue
50	Orange	White	Violet	Slate
51	Green	White	White	Blue
52	Green	White	White	Orange
74	Green	White	Violet	Brown
75	Green	White	Violet	Slate
76	Brown	White	White	Blue
77	Brown	White	White	Orange
99	Brown	White	Violet	Brown
100	Brown	White	Violet	Slate

73.38

Identifying Binder Groups

Upon removing the core wrapper, have ready some short pieces of paired conductors with colors matching the color code of the binder groups. Place a matching color pair around each binder group and pigtail the ends of the tie wires. The binder threads or tape can then be removed from the binder groups.

Mount the base assembly for the ready-access closure. The tape which was placed to mark the splice opening may then be removed.

Place the groups in a convenient position, so you can proceed with splicing the conductors.

Splicing the Conductors

Figure 13-17 shows one method of splicing the conductors, a method which includes the use of a plastic-filled sleeve. This method requires that the wires first be twisted with three loose turns. Strip off the insulation and make five firm half-turns, cut off the excess wire leaving about 1 inch of twisted bare wires, and solder with resin core solder. Then slip the filled sleeve over the joint and bend the splice into position.

Figure 13-18 shows the use of a sealing-type splicing connector. The conductors are twisted enough to hold the pair of wires together, and the connector is slipped over the ends of the wires approximately 3 inches from the beginning of the twist. A hand-operated crimping tool is used to crimp the connector. DO NOT remove the insulation from the ends of the wires when using this method, because the insulation on the wires keeps the conductors centered in the connector.

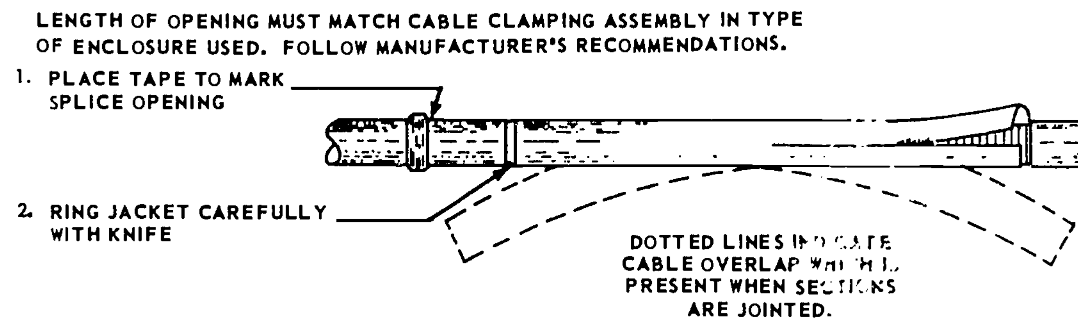
When a pair of conductors dead end in a splice, turn back 3/4 inch of one conductor and place a filled plastic sleeve over the end of the pair of conductors, as indicated in figure 13-18.

Layup of Spliced Conductors

The number of splice bundles required for a convenient layup will depend on the length of the splice opening and the size of the cable. The splices must be placed in uniform bundles and distributed to give a uniform shape to the full length of the splice area. After the bundle is completed, it should be bound with layers of vinyl tape. Figure 13-19 shows a well-shaped splice bundle.

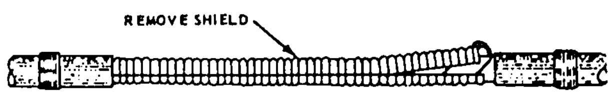
Closing the Splice

After the splices are complete and the bundles are taped, the closure is spread open, slipped



73.204

Figure 13-13.—Splicing opening in polyethylene cable.

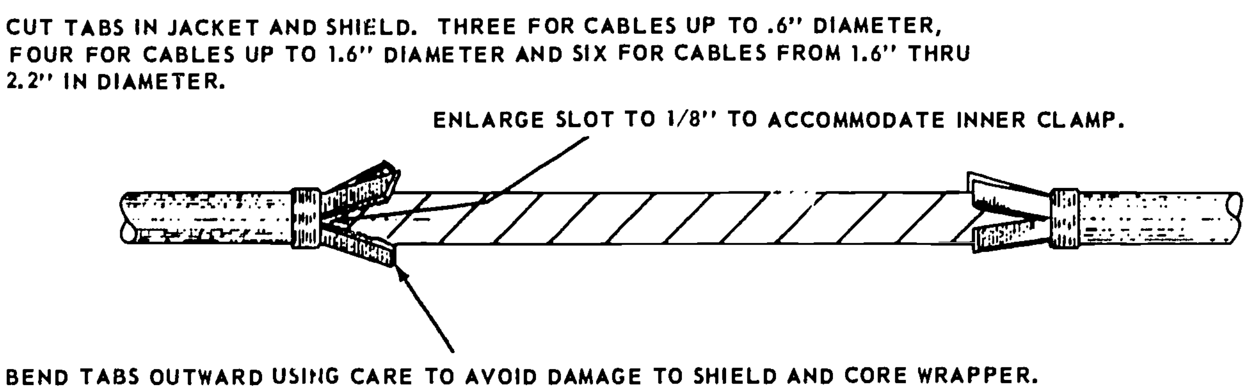


73.205

Figure 13-14.—Removing the shield.

to terminal closures on other poles. Figure 13-21 shows the parts of a closure. When fewer than four cables are brought out, the openings in the nipples not being used are plugged with plugs made for the purpose.

Figure 13-22 shows a closure made for terminal blocks. When only one cable enters, the vacant nipple is plugged.



73.206

Figure 13-15.—Cutting tabs in jacket and shield.

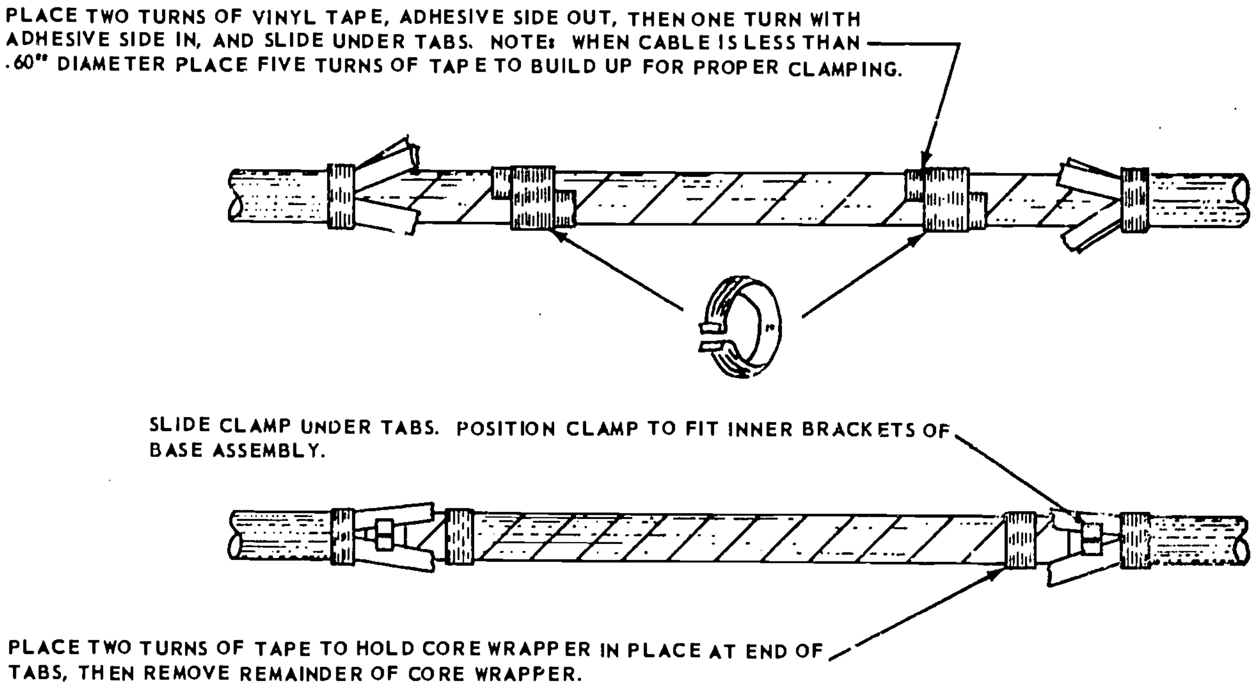
over the bundle and snapped in place over the entire assembly. This closure is made of polyethylene or neoprene, and when it is placed over the splice assembly in the proper manner and fastened with the clips which come with the kit, the splice will be completely weatherproof, but still easily accessible should the need arise to reopen the closure.

Figure 13-20 shows two splice closures in place. The cables leaving the lower nipples run

SPLICING PLASTIC-SHEATHED CABLE TO LEAD-SHEATHED CABLE

The method described here for joining plastic-sheathed, plastic-insulated cable to lead-sheathed, paper-insulated cable may be used on aerial, direct-burial, or duct installations. The method is illustrated in figures 13-23, 13-24, and 13-25.

First mark the cable sheath with the location of the splice and place additional marks a



73.207

Figure 13-16. — Placing clamps under tabs.

standard distance on either side (4 inches on lead, 7 inches on plastic). With aerial-type cable, the cable on either side of the splice should lie along the suspension strand without tension when the strand is at normal tension. The length of the splice opening and the size of the lead sleeve required are shown in figure 13-23.

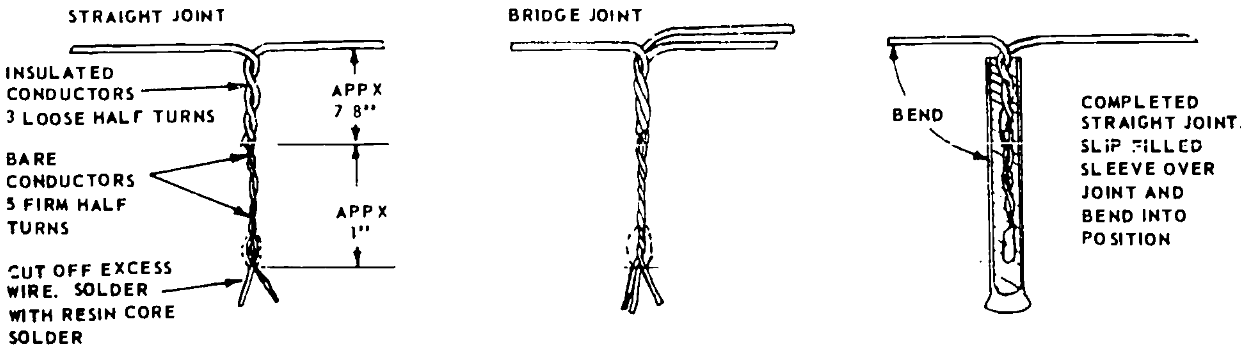
On the lead sheath end, carefully remove the desired amount of sheath so that the core wrapper or the insulation around the conductors will not be damaged. Scrape the surface of the lead 4 inches from the point where the sheath was cut, making sure to remove all dull spots and streaks to present a clean surface for wiping the lead joint. Coat this cleaned space with stearine. Then remove the core wrapper from the exposed cable.

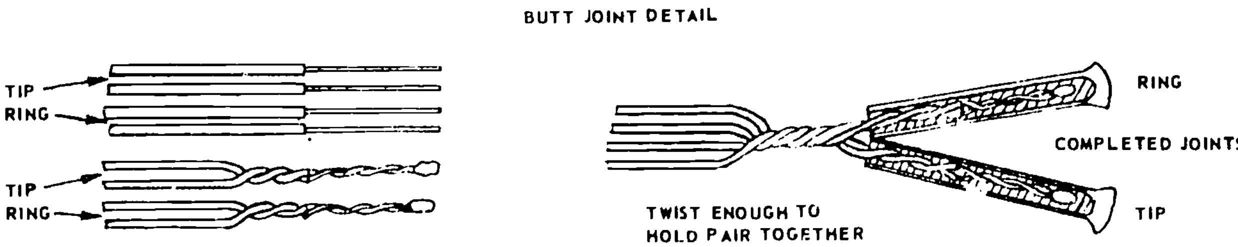
On the plastic cable end, remove the sheath carefully for the desired distance so that the metal shield, the core wrapper, and the insulation around the conductors will not be damaged. Scuff the sheath of the cable for a distance of 7 inches from the opening, using No. 2 1/2 grade sandpaper. Do not use emory paper or cloth. This scuffing will ensure a satisfactory surface for the proper adhesion of the end seal casting and for the subsequent taping operations. Turn back the shield and remove the core wrapper to the end of the sheath opening.

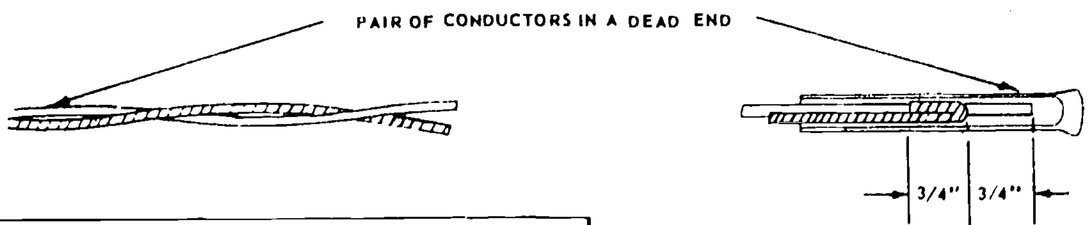
Select a lead sleeve of proper size. Clean the outside of the sleeve for a distance of 7 inches from the end toward the plastic-sheathed cable, and for a distance of 2 inches from the end toward the lead-sheathed cable. Place the sleeve over the lead-sheathed cable and push it back out of the way until needed, as shown in figure 13-23.

Casting the Plastic End Seal

Prepare a cone-shaped casting form (one may be made from a cone-shaped paper cup or something similar). Be sure that the largest diameter of the form is not larger than the inside diameter of the lead sleeve being used. Fashion a hole in the bottom of the form to make a snug fit over the plastic-cable sheath. Slide the form over the sheath to a temporary position about 4 inches back from the end of the







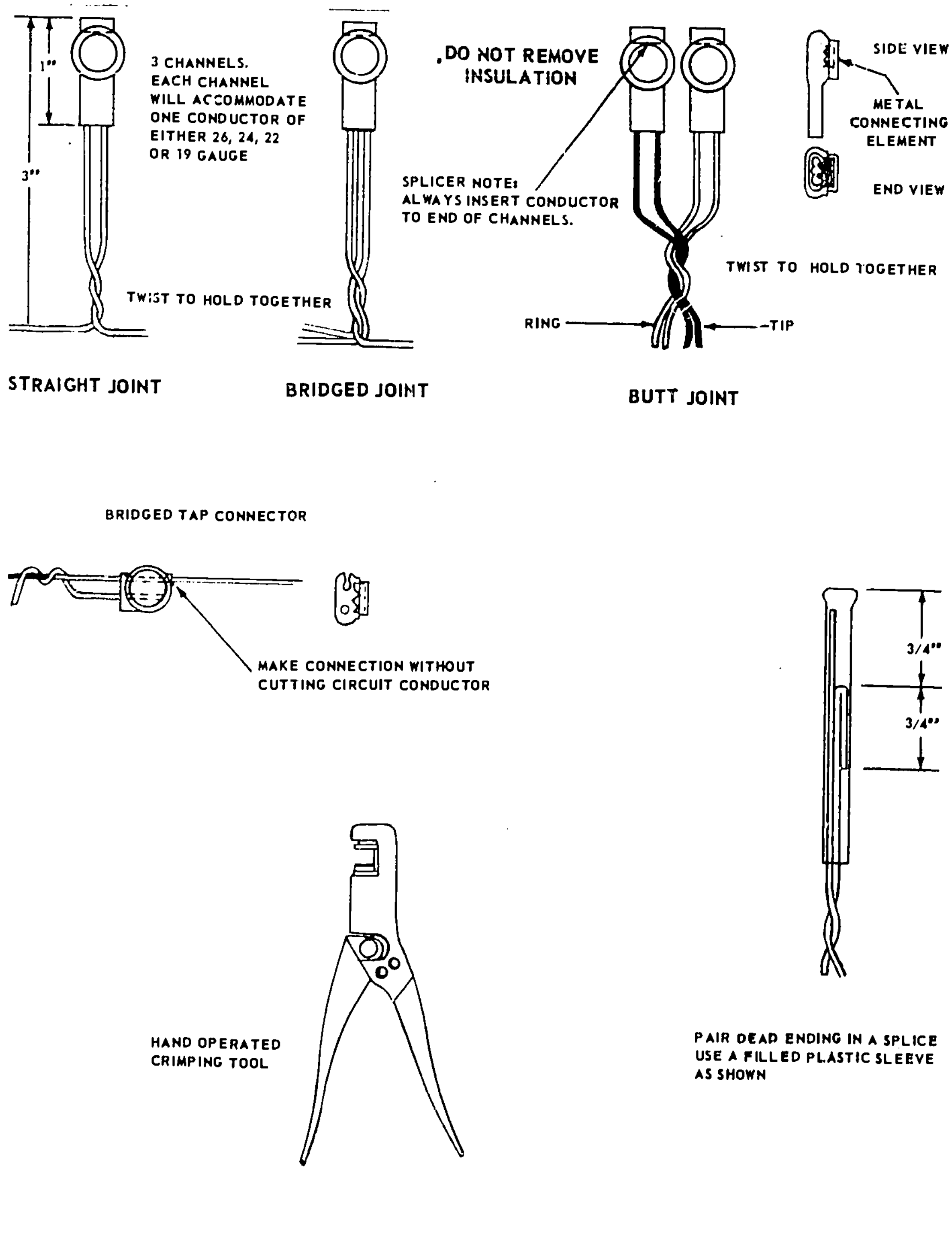
FILLED PLASTIC SLEEVES (LENGTH 2-1/2")			
GAUGE OF CONDUCTORS	TYPE OF JOINTS	INSIDE DIAMETER	COLOR
24X24	STRAIGHT	.085	YELLOW
24X22		.085	"
24X19		.105	GREEN
22X22		.105	"
22X19		.105	"
19X19		.125	CLEAR
24X24X24	BRIDGE	.085	YELLOW
24X24X22		.105	GREEN
24X24X19		.105	"
22X22X24		.105	"
22X22X22		.105	"
22X22X19		.125	CLEAR
19X19X24		.125	"
19X19X22		.125	"
19X19X19		.145	RED

TURN BACK ONE CONDUCTOR OF PAIR AND CAP WITH FILLED PLASTIC SLEEVE. POSITION SLEEVE FOR POSSIBLE FUTURE SPLICING.

PRECAUTION: TO AVOID CRACKING AND LOSS OF FILLER, THE PROPER SIZE SLEEVES SHOULD BE USED AND NOT FORCED OVER JOINTS.

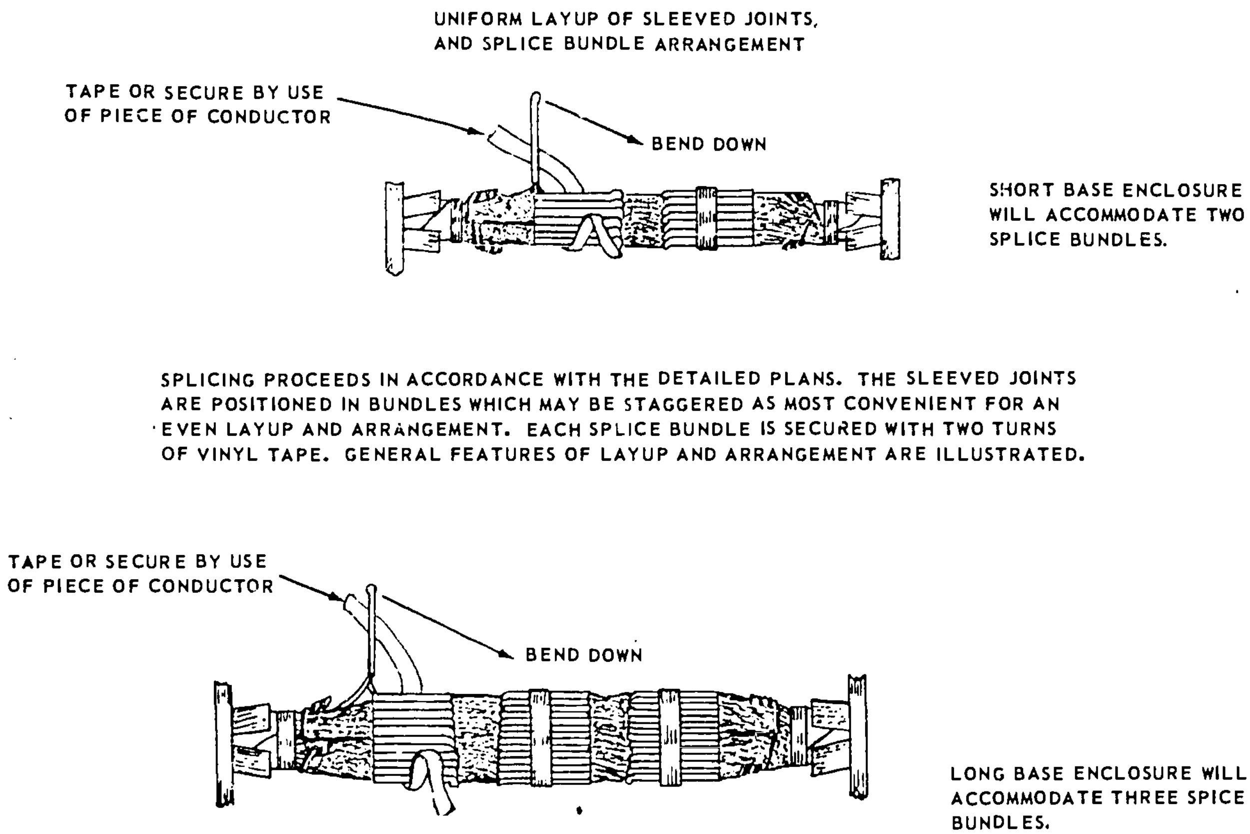
73.208

Figure 13-17.—Splicing details for various types of joints.



73.209

Figure 13-18.—Sealing type splicing connector.



73.210

Figure 13-19.—Layup pattern for splice.

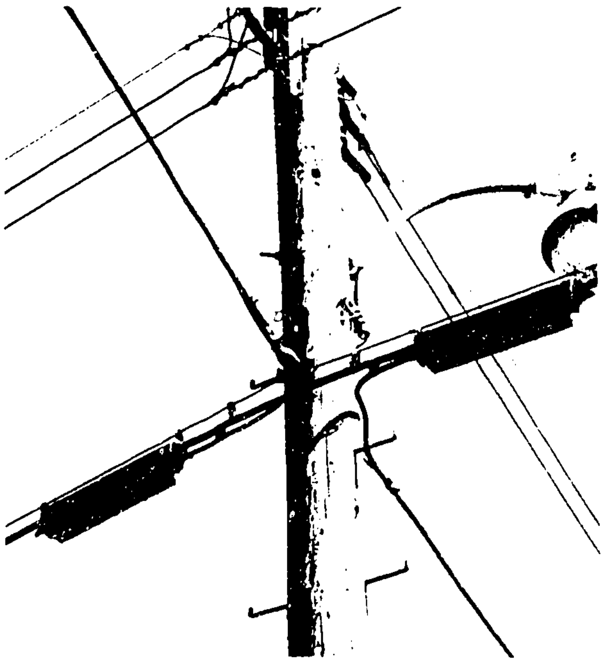
sheath. Turn up the end of the cable and secure it in a vertical position for the casting operation. Spread the conductors to allow space for the casting liquid to completely seal all voids.

Move the casting form up until it extends about 1/2 inch above the end of the plastic sheath. If the lower end of the form is not tight around the sheath, it may be necessary to use a few wraps of tape to hold it in position and seal any openings. Figure 13-23 shows a form in place.

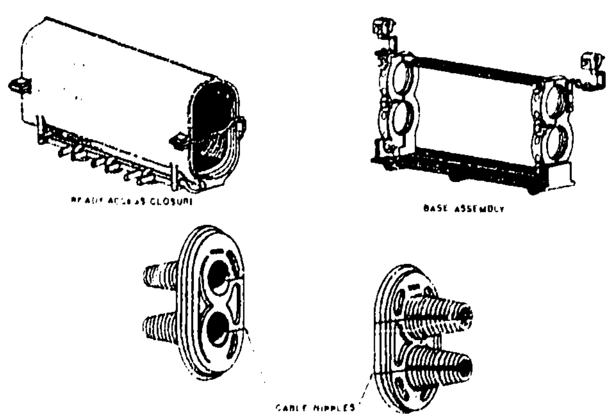
Prepare the casting mixture according to instructions included with the container. You will notice that the casting resin will develop heat immediately after being mixed, but this heat will not cause any harm. When the mixture is ready to pour, pour it into the form until it reaches a point very close to the top. During the pouring process, move the wires and shield slightly to aid penetration and to bring the shield and wires into alignment for the splicing operation. After the form is filled, allow the mixture to harden for approximately 10 minutes, or until it is firm and cool to the touch. Then peel off the form and clean off any particles that may have adhered to the casting. The cable then may be bent back into position for the splicing operation.

Splicing and Soldering Conductors

Separate conductors into bunches by color groups or complements, and secure them in a convenient position for splicing, leaving a suitable length for staggered spacing of splices to attain a uniform layup. Excess wire should then be cut off. As conductors are selected for splicing, plastic sleeves of proper diameter should be placed over one of the conductors and pushed back. Where conductors end in a splice, cut them off and place a sleeve (selected according to fig. 13-24 specifications) over the



73.211
Figure 13-20.— Splice closures in place.



73.212X
Figure 13-21.— Parts of a splice closure.

ends and position it for subsequent use. All sleeves are 3 inches long.

Remove the required length of insulation from the conductors as they are selected for splicing. Twist the individual, skinned conductors together. Make a joint 1 3/8 inches to 1 3/4 inches in length, starting with three loose half-turns (about 1 inch), then finishing with five tight half-turns (about 3/8 to 1/2 inch).

After the excess wire has been cut off, solder the joint using resin core solder. Bend the soldered pigtail into place, and slide the previously placed sleeve over the joint, as shown in figure 13-24.

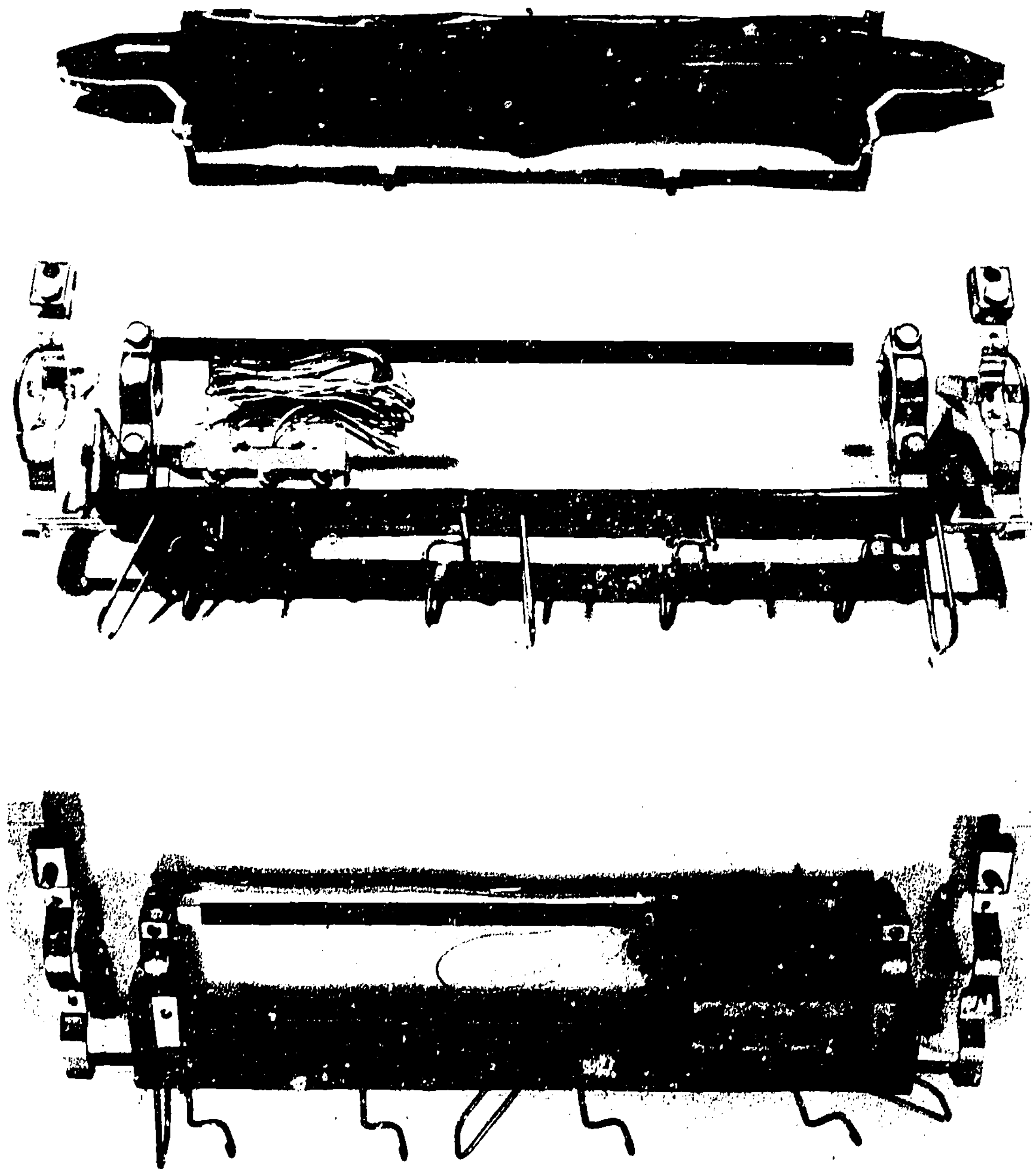
After all conductors have been spliced and placed in the proper layup, wrap the body of the splice with a plastic envelope cut from a sheet of polyethylene or the equivalent. Fill the envelope with desiccant in amounts for various sizes of cable as shown in figure 13-24. BE SURE NOT TO EXCEED THE RECOMMENDED AMOUNTS.

Cover the whole splice with a single layer of half-lapped-vinyl tape, but do not overlap the cable sheath or metallic shield. To ensure continuity of the shield, rewrap the shielding material around the splice, extending in onto the lead sheath. If the shield material is not long enough to make a full wrap around the lead sheath, add an extra piece of shielding and solder it to the existing strip. This soldering operation should be performed away from the cable core to protect the tape from the heat of the soldering iron. Solder the end of the shield to the lead sheath at the point of overlap. On aerial-type plastic cable, tin the aluminum shield with Alcoa 64 aluminum flux and solder it with 50-50 or resin core solder.

Placing the Sleeve

Place a strip of tape on the plastic sheath extending lengthwise about 2 1/2 inches from the base of the cast end seal, as shown in figure 13-25. Secure a strip of wire cloth 2 inches wide, starting the edge of the wire cloth on the strip of tape and wrapping tightly around the cable, overlapping the starting point about 1 inch.

Secure the edges of the wire cloth in place with tape. Hold a hot soldering iron firmly against the wire cloth at numerous points around the sheath until dark patches appear through the wire mesh. This operation will, by softening the plastic, anchor the wire cloth in the plastic sheath. Be careful not to hold the iron too long in one place, or the insulation may be burned.

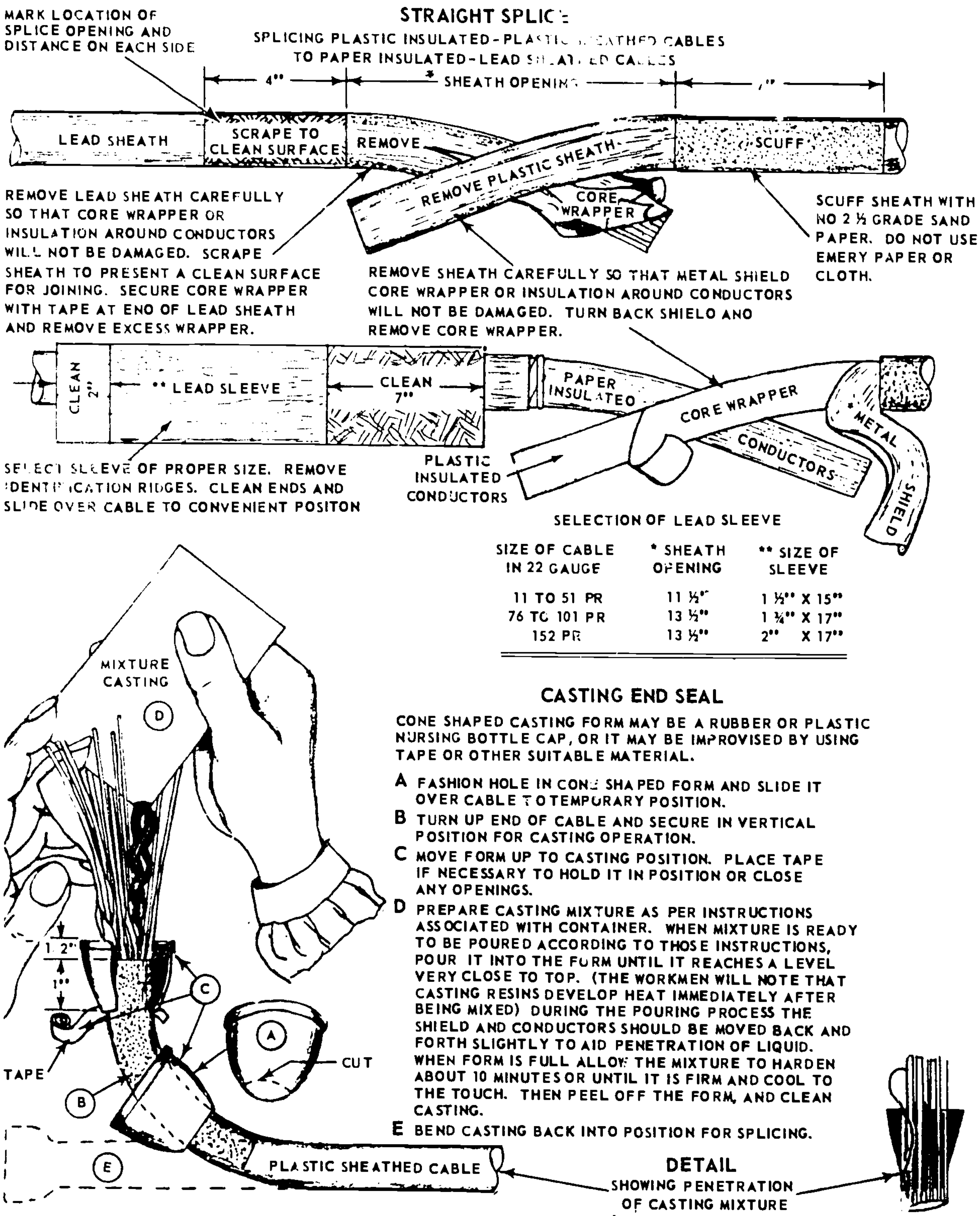


73.213

Figure 13-22. — Terminal-block closure.

Place the lead sleeve in position over the splice, overlapping the lead-cable sheath about 1 1/2 inches, and overlapping the wire cloth on the plastic sheath about 1 inch. Beat in the end of the sleeve o. the lead-sheath side and wipe in the usual manner.

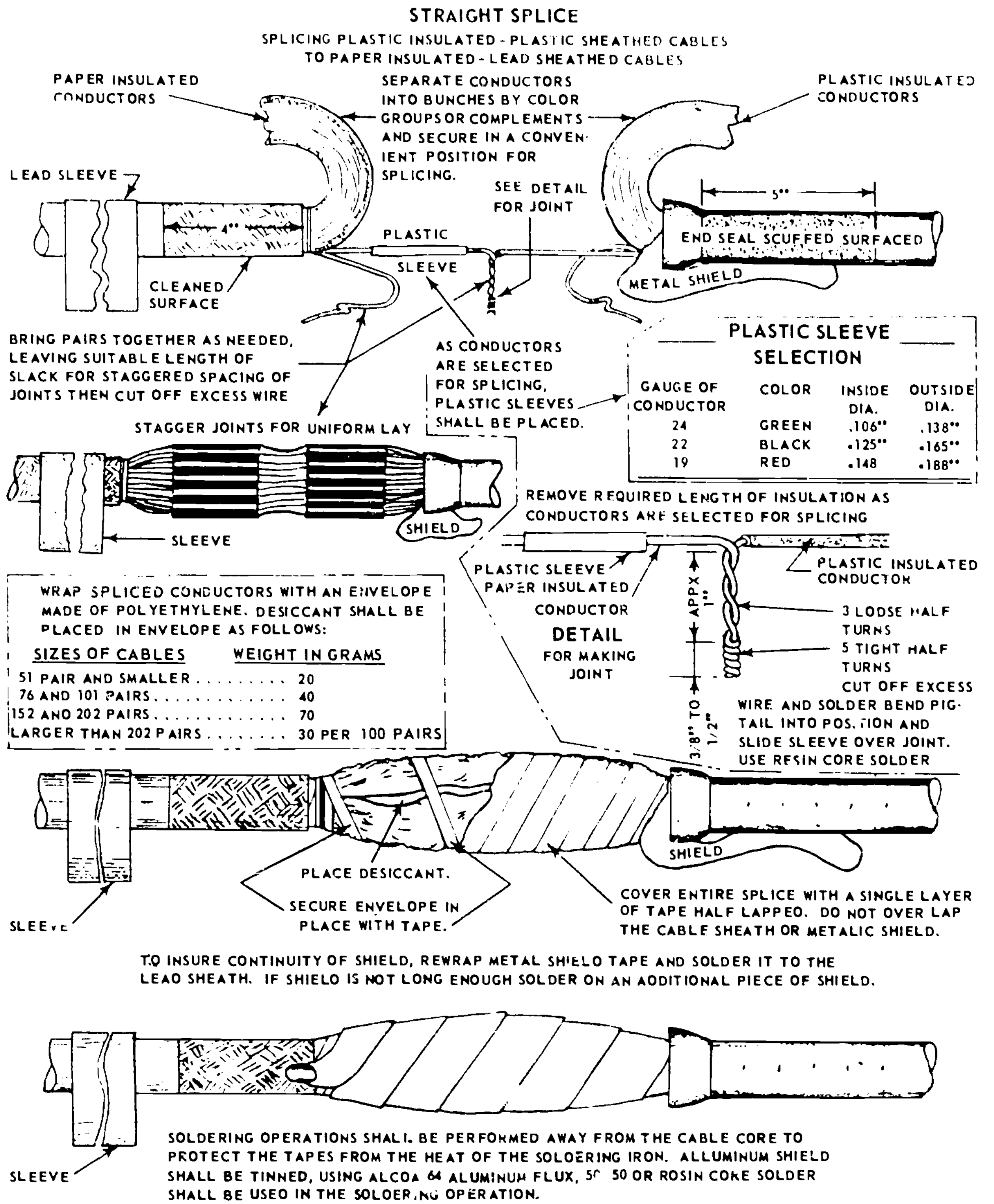
On the plastic-sheath side, shape the end of the lead sleeve to the copper-wire cloth in a gradually tapering slope. This will tend to make the taping operation easier. Solder the lead sleeve to the wire cloth, using resin-core solder and a soldering copper.



SIZE OF CABLE IN 22 GAUGE	* SHEATH OPENING	** SIZE OF SLEEVE
11 TO 51 PR	11 ½"	1 ½" X 15"
76 TO 101 PR	13 ½"	1 ¾" X 17"
152 PR	13 ½"	2" X 17"

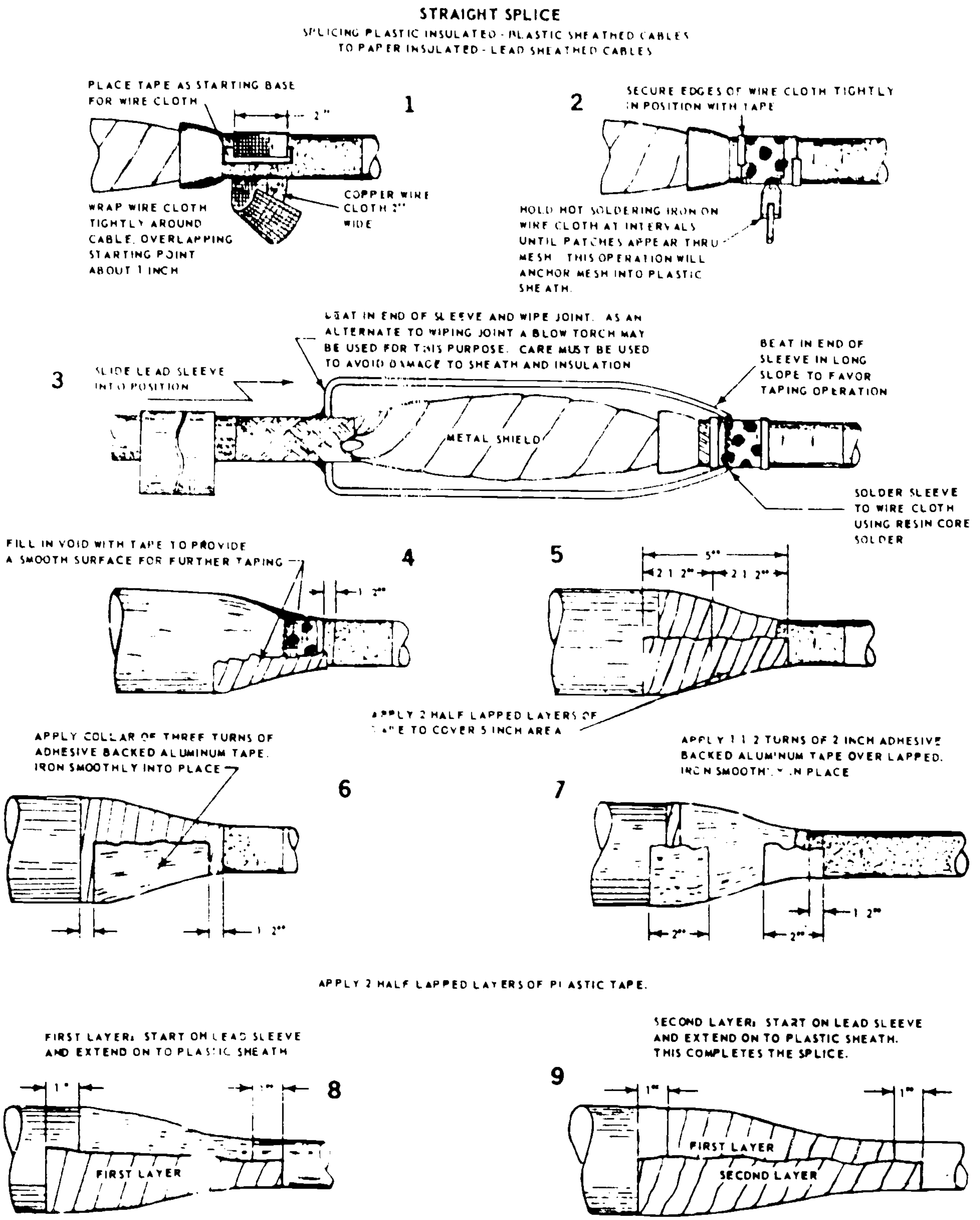
73.220

Figure 13-23. — Preparing to splice plastic-sheathed cable to lead-sheathed cable.



73.221

Figure 13-24.—Making the splice of plastic-sheathed cable to lead-sheathed cable.



73.222

Figure 13-25. Completing the splice of plastic-sheathed cable to lead-sheathed cable.

Fill in the void between the plastic sheath and the lead sleeve with vinyl tape, to provide a smooth surface for further taping. Figure 13-25 shows the taping procedure. Apply two half-lapped layers of tape, extending 2 1/2 inches on each side of the point where the lead sleeve is joined to the wire cloth (a total of 5 inches). Apply a collar of three turns of 3-inch adhesive-backed aluminum tape and iron smoothly in place with a cable dresser. This operation will allow 1/2 inch of previously placed vinyl tape to show at each end of the collar.

Apply one and a half turns of 2-inch adhesive-backed aluminum tape at each end of the collar, overlapping the previously placed aluminum tape about 1/2 inch. Iron smoothly with a cable dresser. Two-inch tape may be cut from a roll of 4-inch tape.

Apply two half-lapped layers of vinyl tape over the aluminum tape. Start the first layer on the lead sleeve 1 inch from the aluminum tape, and continue to a point on the plastic sheath 1 inch beyond the aluminum tape. Start the second layer of tape on the lead sleeve 1 inch from the end of the previous layer, and wrap to a point 1 inch beyond the end of the first layer.

This completes the splicing operation.

SPLICING POLYETHYLENE CABLE FOR DIRECT-BURIAL INSTALLATION

Direct-burial cable is buried in a trench, usually at least 30 inches below the surface. When a splice must remain aboveground, splice or terminal housings are used. When no external housings are permitted, a casting compound and special splicing technique are used to allow the splice to remain underground.

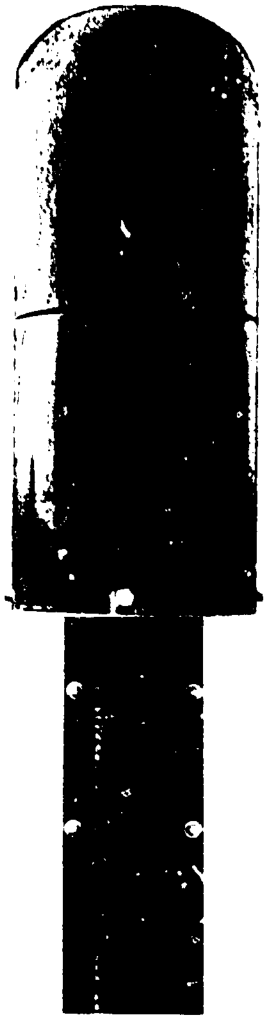
When the cable changes from direct-burial cable to aerial cable, the housing is usually pole-mounted. However, when a terminal block to connect lines to a telephone is needed, or when a splice is to be made in the cable, a pedestal-mounted housing is used.

Figure 13-26 shows a pedestal-mounted, open-terminal housing with three pairs of conductors connected to the terminal block. In this type of housing the conductors passing through the housing (not connected to the terminal block) are not cut, but are continuous through the housing.

73.214
Figure 13-26.—Open-terminal housing.

Figure 13-27 shows the housing with cover in place.

An example of a splice housing is shown in figure 13-28. Figure 13-29 shows the splice housing with cover in place. Continuity of the



73.215
Figure 13-27.—Terminal housing with cover in place.

shield in direct-burial cable is accomplished by means of a bonding harness as shown in figure 13-30.

When no external housings are permitted, casting compound is used to minimize the problem of moisture. This technique is outlined in figure 13-31.

REPAIR OF LEAD-COVERED CABLE

Making minor repairs because of ring cuts, sheath breaks, lightning burns, bullet holes, or

73.216
Figure 13-28.—Splice housing.

other damage to small aerial cable is part of your job. Such damage can be repaired with an acetylene torch if it does not extend through the sheath.

Water-soaked paper insulation usually causes pairs to become shorted. It follows that shorted pairs are frequently an indication that somewhere the sheath is damaged enough to allow moisture to penetrate to the insulation.

Steps in making a sheath-damage repair are as follows:

1. Opening the sheath.

2. Drying out and repair.

3. Closing the sheath.

73.217
Figure 13-29.—Splice housing with cover in place.

4. Soldering the seam, using a soldering copper or an acetylene torch.

OPENING THE SHEATH

After the fault has been located and the ladder or splicing platform has been placed for gaining access to the repair point on the cable, proceed to open the sheath as follows:

1. Straighten the cable if necessary, and reduce cable tension, also if necessary, by placing grade clamps.

2. Use a wire brush to brighten the lead sheath in the section to be split.

3. Rub stearine along the cable where the lengthwise split is to be made. As the cut is made, continue to lubricate with stearine.

4. Split the cable with a cable stripper, a cutting tool with small and large blades which can be set to cut a given depth. Adjust the small blade of the stripper so that it will penetrate 1/32 to 1/16 inch. Make the starting cuts with the small end of the blade, routing out the small lead shavings as you cut. After a definite line of cut has been established, turn the stripper over and use the large end of the blade to bevel the cut. Do not cut all the way through the sheath with the large end. Just before the blade is about to break through the sheath, reverse the tool and complete the cut with the small end.

5. After you have cut through the sheath, open it with a pair of cable pliers. Grasp the handles of the cable pliers firmly and open the incision on one side. With the sharp jaw in the cut, work the pliers sideways, exerting a small downward pressure at the same time. Bend the sheath cautiously, so as not to deform it. When one side of the sheath is bent back, repeat the process on the other side.

When the sheath has been opened, push out the cable by inserting wooden wedges between sheath and cable as shown in figure 13-3[illegible].

DRYING OUT AND REPAIR

If wires must be spliced, the cut must be long enough so that splices can be properly staggered. Apply paper tape to any points at which the wire is sound but the insulation has become blackened because of electrolytic action. To apply the tape, pull the pair out and cut a piece of tape long enough to extend at least 1/2 inch beyond the corroded portion. Press it down with your fingers, and trim off the excess. In hot weather take great care that perspiration from your hands does not dampen the insulation. If the conductor insulation is damp or wet, a procedure similar to that described in figure 13-24 may be used, but the envelope and desiccant must be removed to close the sheath as described in the following steps.

After all damaged wires are repaired, push cotton tape under the edges of the sheath with a

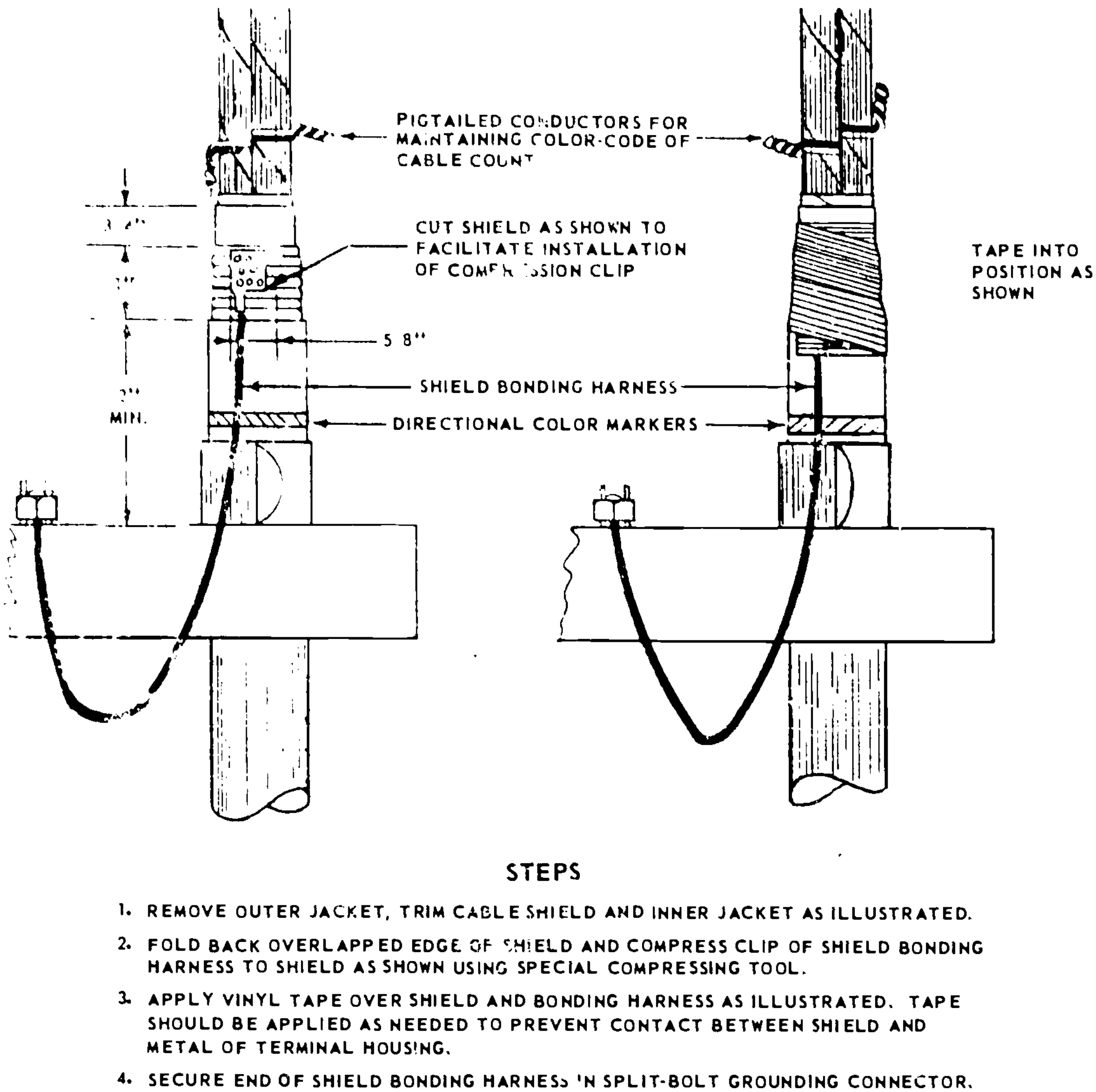


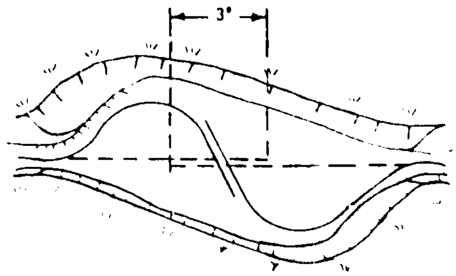
Figure 13-30. — Installation of bonding harness.

butting tool. Wrap the core with 1-inch tape which has been boiled out in paraffin, and then push the core back into the sheath. Test the cable pairs to ensure that all trouble is cleared.

CLOSING THE SHEATH

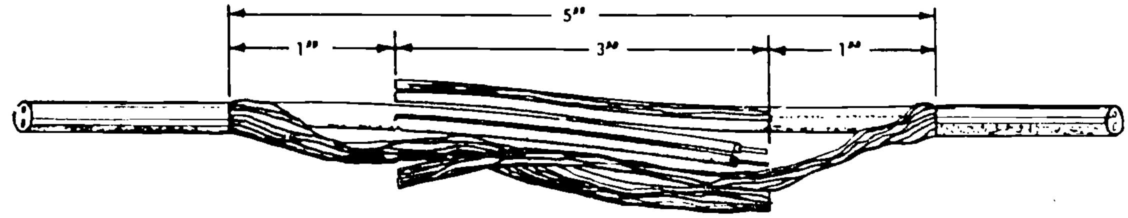
Before closing the cut in the sheath, cut a piece of pressboard about 5/16 inch wide and as long as the length of the opening. Lubricate with stearine generously, so that the edges of the sheath will close readily around the pressboard strip; after removing the wedges and pushing the cable back into the sheath, place the strip under the opening. It is not necessary to close the cut completely, but if it is left partly open, the strip of pressboard should cover the cable so that it will not be damaged during the process of sealing up the split in the sheath.

In closing the sheath you should bend it into shape gradually. First press it together

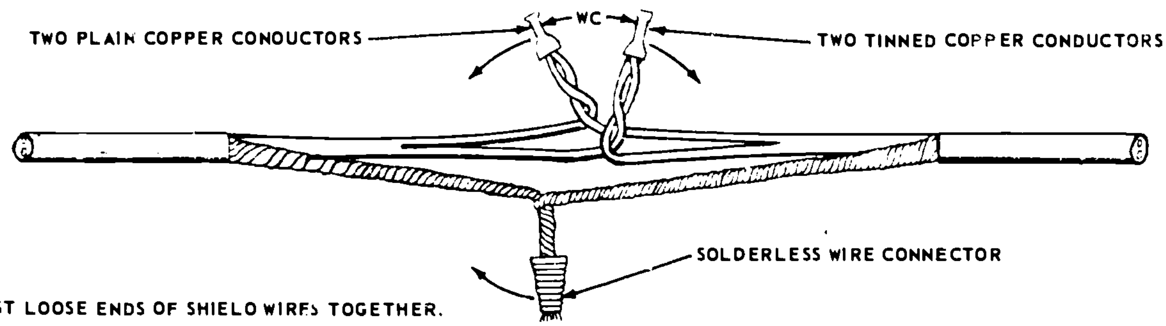


NOTE:

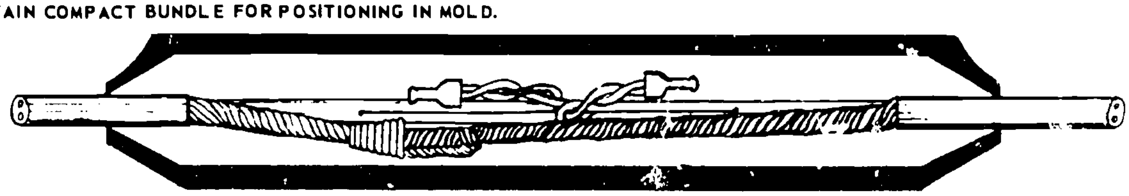
EXCAVATE A TRENCH AS SHOWN, PROVIDE A MINIMUM OF THREE FEET OVERLAP IN THE BURIED WIRE AND PROCEED TO MAKE THE DIRECT BURIAL WIRE SPLICE AS SHOWN IN THE FOLLOWING STEPS:



1. REMOVE APPROXIMATELY 4" OF JACKET FROM ENDS AS SHOWN. CLEAN FLOODING COMPOUND FROM SHIELD WIRES AND CONDUCTOR INSULATION.
2. SLIT INSULATION APPROXIMATELY 3" AND SEPARATE CONDUCTORS.
3. REMOVE APPROXIMATELY 1/4" OF INSULATION FROM CONDUCTORS, INSERT INTO INSULATED WIRE CONNECTORS, CRIMP AND BEND INTO POSITION AS SHOWN.



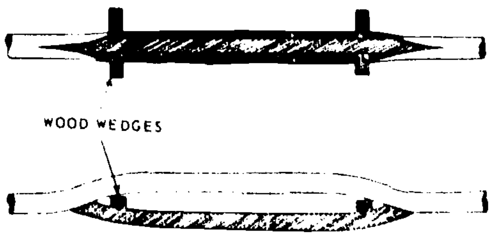
4. TWIST LOOSE ENDS OF SHIELD WIRES TOGETHER.
5. BRING SHIELD WIRES TOGETHER, MAKE PIGTAIL, INSERT ENDS INTO SOLDERLESS WIRE CONNECTOR AND TWIST INTO POSITION.
6. BRING SHIELDS AND CONDUCTOR SPLICES INTO ALIGNMENT AND APPLY TAPE AS REQUIRED TO OBTAIN COMPACT BUNDLE FOR POSITIONING IN MOLD.



7. POSITION MOLD AROUND SPLICE BUNDLE AND APPLY TAPE AT EACH END TO PREVENT COMPOUND MIXTURE FROM LEAKING.
8. SET MOLD IN LEVEL POSITION, PREPARE CASTING COMPOUND AS RECOMMENDED BY MANUFACTURER AND POUR.
9. DO NOT DISTURB SPLICE OR REFILL TRENCH UNTIL CASTING COMPOUND HAS COMPLETELY CURED.

73.219

Figure 13-31.—Splicing polyethylene cable for direct-burial installation.



73.203
Figure 13-32. — Wedging section of cable out of opened sheath.

with your hands, then shape it into its original shape by applying pressure with tongs kept lubricated with stearine. Do not roll the tongs over the sheath, because this will create depressions around the circumference. Take care, also, not to apply pressure directly over the cut until the cable is well shaped, or you may flatten the cable.

SOLDERING THE SEAM

After the sheath has been closed over the cable so that the edges of the cut are from 1/8 to 1/4 inch apart, use the scoring tool and a wire brush to clean the sheath thoroughly. Apply pasters along the edges and ends of the cut, to fix the width and length of the closing seam. Set the pasters about 1/16 to 1/8 inch away from the edges of the cut. Use a half-round bastard file at each end of the cut to form a depression into which solder can be flowed to seal any fine cracks caused by bending back the sheath. After the pasters are set, apply stearine to the portion to be soldered.

Using a Soldering Copper

Fuse stearine core solder to the cut by holding the end of the solder bar in contact with the sheath. Hold the handle of the soldering copper in one hand at a 45° angle to the cable. Rest one beveled edge of the copper on the paper paster at one end of the sheath opening. Move the iron onto the sheath along the opening while feeding bar solder (held in the other hand) to the vertical beveled edge of the copper ahead of the iron. The copper must be kept moving at a speed just slow enough to fill the opening with the solder and fuse it to the sheath.

Part of the copper edge resting on the sheath must also rest on the paper paster along one side of the opening to make a smooth continuous seam. There will be a slight buildup as the molten solder streams out from behind the copper. It may be necessary to pass the copper along the other paster to dress up the seam. After completing the soldering operations, remove the pasters.

Using an Acetylene Torch

Small sheath defects, such as ring cuts and cracks, can be repaired by acetylene torch. Acetylene, however, is a highly flammable gas which is explosive in confined spaces. Consequently, never use the acetylene torch for making repairs in a manhole or other enclosed space. Before you use an acetylene torch, be sure you fully understand its operation and particularly, the safety precautions that go with it.

To make sheath repairs with an acetylene torch, you again use stearine core solder. Thoroughly clean the area around the defect with a brushing motion. Apply the torch flame to the cleaned area, being careful not to concentrate long on one spot. Apply solder over the area of the defect, using sufficient heat to tin thoroughly. Build up enough solder to fill the crack or depression. Use a small finishing cloth to pack the solder into the defect, and to smooth off the patch so that is is only slightly more than flush with the surface of the sheath. A repair should extend from 1/4 to 1/2 inch beyond the defect.

Never keep the torch lighted except when making repairs. If spots to be repaired are close together, you may move from one to the other without extinguishing the torch, if you don't have to change position radically. However, if you have to change position or pass a hole, turn off the torch, and relight again in the new position.

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CHAPTER 14

ADMINISTRATION

As a CE3 or 2, you still have a great deal to learn about your trade, including the development of skills required in performing tasks concerning electrical generating and distribution systems and service. And from time to time you will be called upon to fill the role of supervisor. Your duties and responsibilities as a supervisor will be limited, but they will gradually increase as you advance from one pay grade to the next. This chapter discusses one of the major responsibilities of a supervisor—administration. It is not intended to tell you all you need to know about the subject, but to give you some idea of what you, as a CE3 or CE2, can expect in the way of administrative duties. As part of this chapter, information also is included on the purpose of the Personnel Readiness Capability Program (PRCP).

ASSIGNMENT AS CREW LEADER

As you gain experience in construction work, you will probably be called upon to serve as crew leader of CE teams (or crews) consisting of 3 to 5 men. These teams perform various types of work. For example, a three-man team (two linemen and one groundman) may be assigned the job of mounting crossarms and racks on poles. The groundman readies all bolts, washers, nuts, braces, and crossarms to be used. The groundman attaches the handline to the crossarm in the prescribed manner for the lineman to pull into a working position. After the lineman inserts a through-bolt, he casts off the upper half-hitch, and the groundman then heaves the crossarm level. The lineman fastens the braces to the crossarm in a secure manner. When double crossarms are used, they are fastened together at the ends with double-arm bolts allowing for the lineman to adjust the spacing between them. As the supervisor in charge of a job like the one described, you would be in charge of all operations, and be responsible for the care and maintenance of the equipment.

Your duties as a crew leader will 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 discussion, 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. The following pointers will aid you in planning day-to-day work assignments for work teams.

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 excessively 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 log of materials left over. But don't have your material estimate so low that you may run out of necessary items and delay the job so that your men may remain idle, until more materials can be obtained. At times, circumstances come about that make it necessary to use more materials than anticipated.

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.

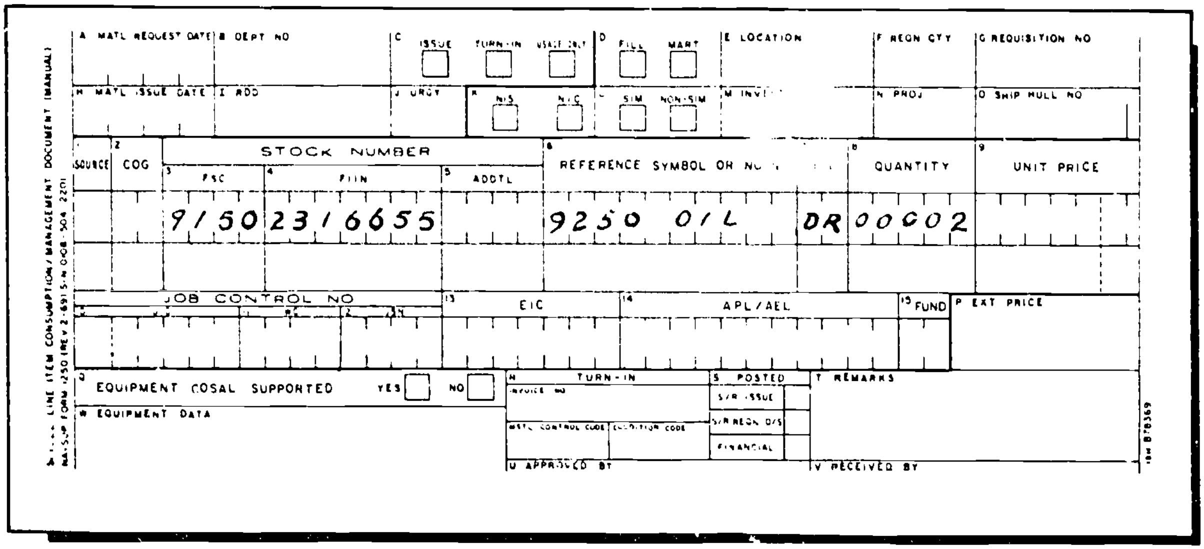
While the job is underway, check from time to time to ensure that the work is progressing satisfactorily. Determine if the proper methods, materials, tools and equipment are being used. If a man is doing a job wrong, stop him and point out what he is doing wrong. Then explain the correct procedure and check to see that he follows it. In checking the work of your men, try to 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. 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 as supervisor a big challenge and endeavor to become proficient in all areas of the supervisor's job.



17.84
Figure 14-1.—Single Line Item Consumption/Management Document (Manual); NAVSUP Form 1250.

PREPARING REQUISITIONS

As a crew leader, you must be able to prepare requisitions, 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.

Two forms used for requisitioning materials are the Single Line Item Consumption/Management Document (Manual), NAVSUP Form 1250 (fig. 14-1) and the Requisition and Invoice/Shipping Document, DD Form 1149 (fig. 14-2).

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 reference symbol or name 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.

TIMEKEEPING

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-by-day accumulation of labor utilization data in sufficient detail and in a manner that allows ready compilation of information required by the Operations Officer

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

REQUISITION AND INVOICE/SHIPPING DOCUMENT

SHEET NO. 1 | NO. OF SHEETS 1 | 5. REQUISITION DATE 8 Dec 1972 | 6. REQUISITION NUMBER 0450A1

1. FROM: EQUIPMENT DIVISION, NAVSCOLCONST

7. DATE MATERIEL REQUIRED: 9 DEC 1972

8. PRIORITY: 10

2. TO: SUPPLY DEP'T.
U.S. NAVAL SCHOOLS CONSTRUCTION
CBC, DAVISVILLE, R.I.

9. AUTHORITY OR PURPOSE: R.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.

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
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: ISSUED BY | TOTAL CONTAINERS | TYPE CONTAINER | DESCRIPTION | TOTAL WEIGHT | TOTAL CUBE

CHECKED BY

PACKED BY

← TOTAL →

19. RECEIPT: CONTAINERS RECEIVED EXCEPT AS NOTED | DATE | BY | SHEET TOTAL

QUANTITIES RECEIVED EXCEPT AS NOTED | DATE | BY | GRAND TOTAL

POSTED | DATE | BY | NO. RECEIVER'S

DD FORM 1 MAR 59 1149 (11 PT) 51 52 53 54 55 56 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

REPLACES EDITION OF 1 MAY 56 WHICH MAY BE USED

468

Figure 14-2.—Requisition and Invoice/Shipping Document, DD Form 1149.

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

...ON AND INVOICE/SHIPPING DOCUMENT

SHEET NO.	NO. OF SHEETS	5. REQUISITION DATE	6. REQUISITION NUMBER
1	1	8 Dec 1972	0450A1 /

...Division, NAVSCOLCONST

7. DATE MATERIEL REQUIRED	8. PRIORITY
9 Dec 1972	10

...Dep't.
...Schools Construction
...isville, R.I.

9. AUTHORITY OR PURPOSE: R.A. Parker, EOC, USN

10. SIGNATURE

11a. VOUCHER NUMBER AND DATE

b.

12. DATE SHIPPED

13. MODE OF SHIPMENT

14. BILL OF LADING NUMBER

...NAVSCOLCONST Grease Rack

15. AIR MOVEMENT DESIGNATOR OR PORT REFERENCE NO.

...	OBJECT CLASS	EXPENDITURE ACCOUNT (From)	(To)	CHARGEABLE ACTIVITY	BUREAU CONTROL ACTIVITY NO.	BUREAU CONTROL NO.	AMOUNT

...BER, DESCRIPTION, AND CODING OF MATERIEL AND/OR SERVICES (b)	UNIT OF ISSUE (c)	QUANTITY REQUESTED (d)	SUPPLY ACTION (e)	TYPE CON-TAINER (f)	CON-TAINER NOS. (g)	UNIT PRICE (h)	TOTAL COST (i)
...0905, Grease, Automotive ...illery (GAA)	CN	5					
...6655, Lube Oil, ...(9250)	DR	2					

17. SPECIAL HANDLING

...	TOTAL CONTAINERS	TYPE CON-TAINER	DESCRIPTION	TOTAL WEIGHT	TOTAL CUBE
			← 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.

...T) 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

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43.3

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

in the management of the manpower resources. It also aids 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 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, and "pipe laying" R-17. 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 14-3 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 14-4. 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 man-hours 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.

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 14-3.—Subcategories of labor.

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, and so on, provides a ready means of predicting future capabilities and requirements. Some of these may be:

1. Construction and military capabilities.
2. Personnel, logistics, and training requirements.
3. Berthing, messing, and housing requirements.
4. 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

CREW LEADER: Johnson EO2 | CREW: Site Preparation and Ditching | CREW SIZE: 6 | TRANSFERS THIS DATE: None

PROJECT: Fleet Recreation Facility Sewage Distribution System | DATE: 11 JAN 19-

NAME	PRODUCTIVE LABOR CODE — DIRECT R 13	DIRECT R 16	INDIRECT (X) X 01	OTHER (M, D, T) T 04	OTHER (M, D, T) T 05	OVERHEAD LABOR CODE (Y) Y 02	OVERHEAD LABOR CODE (Y) Y 11
Smith	6					2	
Good	7						1
Evans		7					1
Gilbert	6		1	1			
Allen		6				2	
Sullivan		6			2		

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

54.309

Figure 14-4. — Daily labor distribution report form.

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. He will then 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 to see 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.

BATTALION SAFETY ORGANIZATION

As a petty officer, you must be familiar with the safety program at your activity. This is important since you cannot function effectively as a petty officer unless you are aware of how you fit into the scheme of safety. You should know who (or what group) arbitrates and establishes the safety policies and procedures you must follow. You should also know who provides guidelines for safety training and supervision. Every naval mobile construction battalion (NMCB) is required by the Naval Construction Force Safety Manual to implement a formal safety organization.

The NMCB's safety organization is composed of two elements as shown in figure 14-5: one to provide for the establishment of safety policy (view A), the other to provide for control and reporting (view B).

SAFETY POLICY ORGANIZATION

The policy organization of a battalion as illustrated in figure 14-5, view A, is broken down into three kinds of committees: (1) the safety policy committee; (2) the supervisor's committee, and (3) the equipment shop or crew committee.

The SAFETY POLICY COMMITTEE is presided over by the executive officer. Its primary purpose is to develop safety doctrine and policy for the battalion. This committee reports to the commanding officer, who must approve all changes in safety policy.

The SUPERVISORS' COMMITTEE is presided over by the battalion's safety chief and is made up of safety supervisors assigned by company commanders, project officers, or officers in charge (OIC's) of detail. This committee provides a convenient forum through which one crew can inform another of its work procedures, safety precautions, and safety suggestions received from crews or individuals. This committee sends its recommendations to the policy committee.

The EQUIPMENT, SHOP, or CREW COMMITTEE is assigned as required. Alfa company has an equipment safety committee presided over by the "A" company chief. The other companies use either the crew or shop committee, both of which are usually presided over by the company or project safety supervisor. The main objective of these committees is to propose changes to the battalion's safety policy, when required, to eliminate unsafe working conditions or prevent unsafe acts. This committee is YOUR CONTACT for recommending safety improvements. In addition to the above, the equipment committee must review all vehicle accident reports, determine the cause of the accidents, and make recommendations for corrective action. As a crew leader, you can expect to serve as a member of either an equipment crew, or shop safety committee. All three of these committees forward reports and recommendations to the supervisor's safety committee.

SAFETY CONTROL AND REPORTING ORGANIZATION

The Safety Control and Reporting Organization follows the regular chain of command. As a crew leader, you will be held accountable for industrial accidents involving personnel under your supervision. The number and types of accidents will be taken into account by your supervisor in rating your ability to supervise. It is the direct responsibility of each crew leader to:

1. Ensure that every man under his supervision is thoroughly familiar with the trade

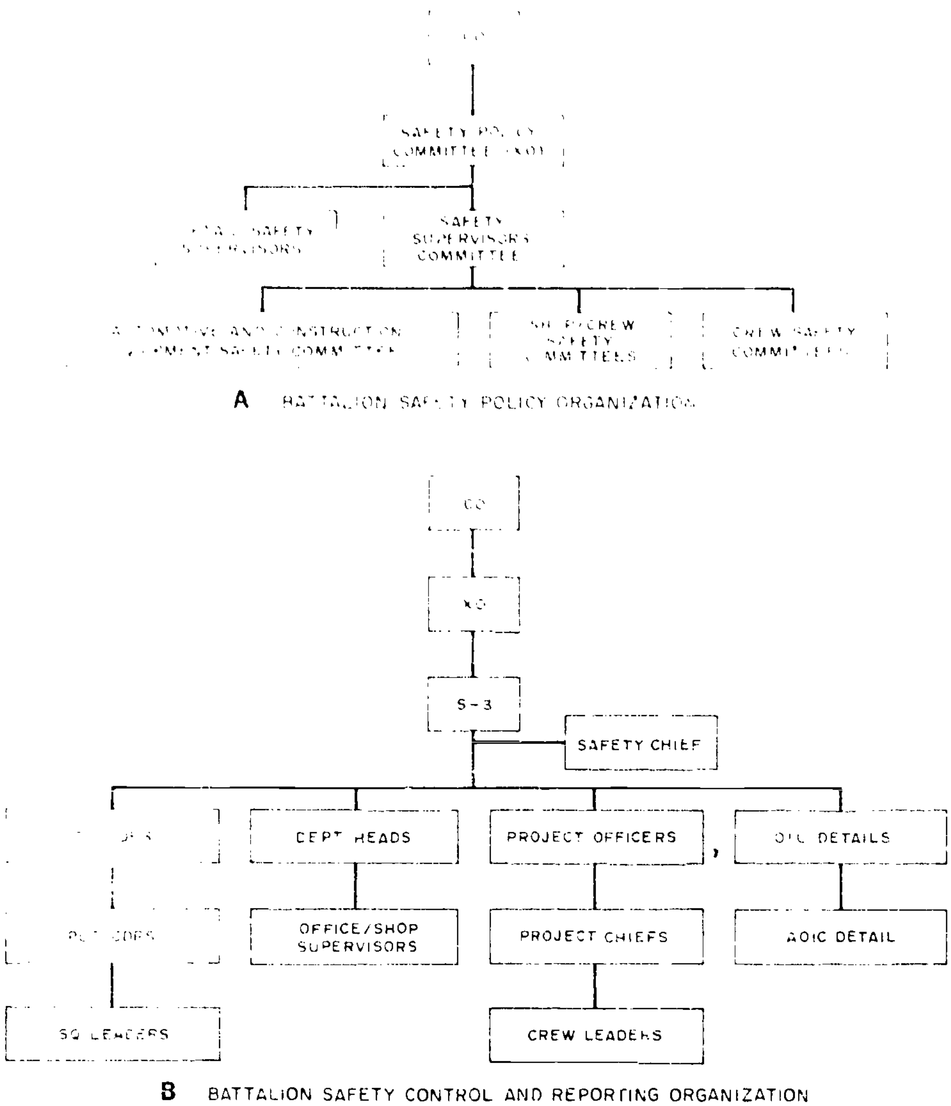

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Figure 14-5. — Battalion safety policy organization.

procedures, techniques, rules, and regulations applicable to the man's safe conduct and work performance, and to make sure the man has a general understanding of all pertinent safety regulations.

2. Ensure that all subordinates make proper use of personal protective equipment and clothing and, if necessary, personally demonstrate its proper use.

3. Personally direct or request from proper authority the correction of unsafe conditions and unsafe practices encountered by those under his supervision, and carry out requests to a satisfactory conclusion.

4. In case of accident, get the injured to proper medical care as quickly as possible.

5. Investigate all accidents involving his men, determine the causes (carelessness, thoughtlessness, negligence and so on are not acceptable), submit required written reports, and promptly apply remedial measures in the form of on-the-job training of all subordinates similarly exposed,

and remove or have permanently corrected all defective tools, materials, machinery, or environment contributing to cause of the accident.

In addition to your responsibilities as a crew leader you, as an individual, are responsible for carrying out safe work practices as directed by higher authority. It is your responsibility to immediately report to your supervisor any unsafe practices or conditions you observe. To aid you in carrying out your responsibilities, you will receive assistance from your supervisors, through special training, and by participation in standup safety meetings. It is also important to note that ALL HANDS are encouraged to submit safety ideas through the safety policy chain of command.

KEY SAFETY PERSONNEL

For success in carrying out your responsibilities in the safety program, you must know who is responsible for what in regard to safety. The three key jobs in a battalion's safety program are: safety officer, safety chief, and safety supervisor.

The SAFETY OFFICER in a battalion is normally the Operations Officer (S3). He is responsible for ensuring that the battalion's safety program meets the requirements of the Naval Construction Force Safety Manual and its references. The Safety Officer is responsible for:

1. Providing continuous safety inspection of all shops and jobsites.
2. Maintaining a safety reference library.
3. Providing assistance in the training of safety supervisors and crew leaders.
4. Ensuring accurate accident reporting.
5. Ordering any safety equipment required for a shop or project when such equipment is not a normal allowance item.

The SAFETY CHIEF is normally an E-7 or E-8 and is assigned full-time to safety. He assists the safety officer in all his duties and is the one you will have the most contact with. He will help you get the training necessary for you and your crew. A major responsibility of the safety chief is to ensure that the battalion's safety program is enforced. If you have a question on safety, he should be able to find the answer. It's important to remember that the safety chief, the safety officer or any other person in a position of authority has the power to stop a job when he has determined an unsafe condition exists—until such condition is corrected.

The SAFETY SUPERVISOR is normally a first class petty officer, who is assigned this collateral duty by his company commander, project officer, or detail OIC. He directs, in an advisory capacity, the safety program of the company project or detail. His responsibilities include the following:

1. Indoctrination of new men.
2. The assembling, coordinating, and dissemination of information for use of crew leaders in their Standup Safety Meeting.
3. Advising the company commander/project officer/detail OIC concerning the safety program, and recommending changes required to eliminate unsafe work practices and hazardous conditions.
4. Compiling accident statistics for his company/project/team and analysis comparing crew leaders. Records should be kept on a monthly basis and all crew leaders informed as to their standing.
5. Reviewing personal protective equipment requirements of the men and advising crew leaders on the correct type of safety equipment to use, where to obtain it, how to use it, and so on.
6. Assuring that crew leaders are provided with sufficient safety information for use in instructing men in their crew.
7. Reviewing all accident reports submitted to the Safety Office, appraising the quality of the report, and assisting the company commander/project officer/detail OIC in making constructive use of the information contained therein.

CHAPTER 15

BASIC ELECTRONIC COMPONENTS AND CIRCUITS

Although there have been many attempts to explain the difference between the meanings of the terms "electricity" and "electronics," they are more alike than they are different. For instance, electricity and electronics are both concerned with the use of electricity to operate equipment. The field of electricity is usually concerned with magnets, generators, motors, lights, and heaters; the field of electronics is concerned with the use of electricity in radio, television, radar, telephone, and other equipment in which electron tubes or transistors are needed.

Current and voltage cannot tell the difference between an electrical circuit and an electronic circuit. The components that have been built into the circuit determine how the current and voltage will be used to make the electrical or electronic equipment work. One of the most recently developed electronic components is the transistor. Transistors are constructed from solid materials, classified as semiconductors, whose resistance to the flow of electrons is between that of insulators and conductors.

Any circuit can be thought of in terms of the effects that resistors, capacitors, and inductors (coils) have on current or voltage. The effect that a resistor has on current or voltage is measured in terms of its resistance; the effect of a capacitor is measured in terms of its capacitance; and the effect of a coil is measured in terms of its inductance. The effect that each of these measurable properties has on current or voltage depends on whether the current is direct or alternating and, if alternating, how fast the current or voltage is changing (frequency).

As a Construction Electrician, therefore, you will find it necessary to test resistors, capacitors, and inductors in an electrical or electronic circuit by measuring or otherwise determining the effects of their properties on the current or voltage of the circuit.

RESISTORS AND CAPACITORS

As you already know, current passing through a resistor generates heat. If too much heat is generated, the resistor will be damaged. Wire in the wound resistor will become open, or some of the carbon in the composition resistor will burn away, thus changing the resistor value.

RESISTOR RATINGS

The current-carrying capacity of a resistor is rated according to the amount of heat it can safely release in a given amount of time. Therefore, a resistor cannot be used in a circuit where current causes heat to build up faster than the resistor can dissipate it.

Since heat is a form of energy, the heat-releasing rate of a resistor is measured in energy units called watts. A composition resistor is usually rated at 1/3, 1/2, 1 or 2 watts. The power ratings of wirewound resistors are larger.

RESISTOR TOLERANCES

A resistor rarely measures the exact number of ohms specified by its label or color codes. The amount it varies is called tolerance. Resistor tolerance is given as a percentage value which indicates the amount that a resistor may vary above or below its specified value. Standard tolerances for composition resistors are 5, 10 and 20 percent. Wirewound resistors may have tolerances as low as 1 or 2 percent.

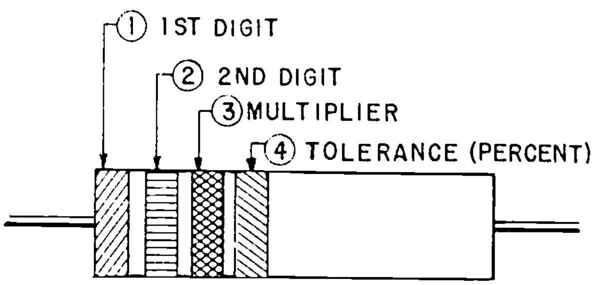
Take a 1,000-ohm resistor with 10 percent tolerance as an example. Ten percent of 1,000 is 100 ohms. Because of the tolerance factor, this resistor will measure somewhere between 100 ohms above and 100 ohms below the labeled value of 1,000 ohms. The range is from 900 to 1,100 ohms.

Resistor tolerance is not an indication of poor manufacturing. Closer tolerances can be achieved, but at greater expense. A resistor with a 20 percent tolerance will cost less than one with a 10 percent tolerance.

RESISTOR COLOR CODES

A wirewound resistor is usually marked with its value in ohms and tolerance in percentage. A color code is used for carbon or composition resistors. For several years, resistance values have been coded by three colored bands painted around the body of the resistor. If the tolerance is either 5 or 10 percent, a fourth color band is used; if 20 percent there is no fourth color band. Positions of the bands are as shown in figure 15-1.

The first two color bands (① and ② of figure 15-1) indicate the first two digits in the colors and numbers table (table 15-1). The third band ③ is the multiplier and indicates the number of zeros



20.373:.374
Figure 15-1. — Color-coded resistor.

Table 15-1. — Colors and Numbers Used to Code Resistors

COLOR	DIGIT	DIGIT	MULTIPLIER	TOLERANCE (percent)
Black	0	0	1	
Brown	1	1	10	
Red	2	2	100	
Orange	3	3	1,000	
Yellow	4	4	10,000	
Green	5	5	100,000	
Blue	6	6	1,000,000	
Violet	7	7	10,000,000	
Gray	8	8	100,000,000	
White	9	9	1,000,000,000	
Gold			.1	5
Silver			.01	10
No color				20

20.373:.374

that follow the first two digits. The fourth band ④ indicates the tolerance and is either gold for 5 percent, or silver for 10 percent.

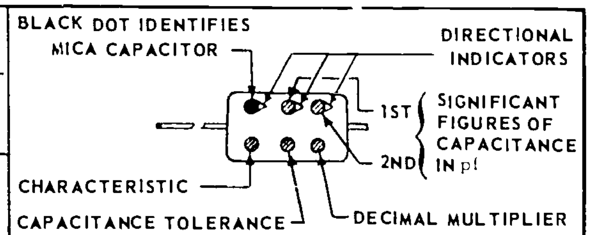
Always use a replacement resistor with a wattage rating equal to or higher than that of the original — never lower. Otherwise, the replacement will burn out. You can use the physical size of the resistor as a guide, if the replacement is the same type (carbon, metallized, or wirewound) as the original. The replacement should be the same physical size or larger.

CAPACITOR COLOR CODING

The value of many capacitors is printed on them, but some use a color-coded system. The color code is the same as that for resistors, but the methods of marking the capacitors differ. The method for fixed mica capacitors is shown in figure 15-2.

A black dot in the upper left corner signifies that the capacitor has a mica dielectric. The center dot in the upper row indicates the first significant figure, and the upper right dot indicates the second significant figure of the capacitance value in picofarads (pF). The right dot in the lower row indicates the decimal multiplier or number of zeros to be added to the right of the two significant figures. The center dot (lower row) specifies the tolerance, which is the possible deviation of the actual capacitor value from that given by its dot markings. The left dot on the lower row deals with the temperature coefficient and applications. As an example, take a capacitor with upper row dots colored black, red, and green (reading from left to right according to the directional indicator). This is a mica capacitor; the significant figures are 2 and 5. Suppose the lower row of dots (reading from right to left) are brown, red, and red. The brown dot requires the addition of one zero to the value of 25, resulting in 250 pF. The red center dot indicates that the actual capacitor value may vary from 250 pF by plus or minus 2 percent. The left red dot means a bypass or silver mica capacitor. Some mica capacitors have only three dots, indicating the first and second significant figures and the multiplier. Their tolerance is 20 percent and their rating is 500 volts. Try reading some of the capacitor values you see in electronic devices when they are exposed to view. Learning to read capacitor values is a matter of practice, much like reading resistor values. There are other types of capacitors whose identification codes vary. See appendix IV of <u>Basic Electricity</u>, NAVTRA 10086-B for the explanation of these codes. Also see appendix II of this manual for a list of prefixes which indicate multiples of basic measuring units.

COLOR	CAPACITANCE		TOLERANCE	CHARACTER-ISTIC
	SIGNIFICANT FIGURE	DECIMAL MULTIPLIER		
BLACK	0	1	20 PERCENT	A
BROWN	1	10		B
RED	2	100	2 PERCENT	C
ORANGE	3	1,000		D
YELLOW	4			E
GREEN	5			F
BLUE	6			G
VIOLET	7			
GRAY	8			
WHITE	9			
GOLD		0.1	5 PERCENT	
SILVER		0.01	10 PERCENT	



CHARACTERISTICS

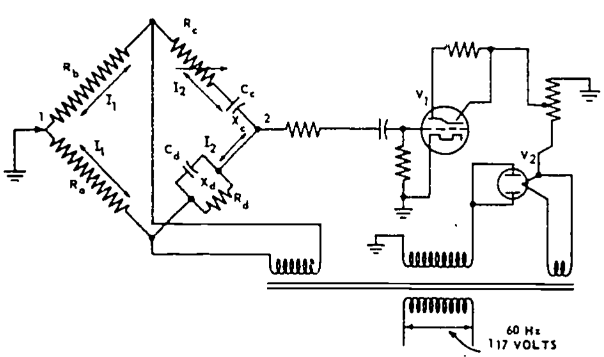
A - ORDINARY MICA BYPASS
B - SAME AS A-LOW LOSS CASE
C - BYPASS OR SILVER MICA (±200 PARTS/MILLION/C)
D - SILVER MICA (±100 PARTS/MILLION/C)
E - SILVER MICA (0 TO +100 PARTS/MILLION/C)
F - SILVER MICA (0 TO +50 PARTS/MILLION/C)
G - SILVER MICA (0 TO - 50 PARTS/MILLION/C)

20.376(71)

Figure 15-2. — Color code for fixed mica capacitors.

CIRCUIT TESTING

Capacitance, inductance, and resistance are measured precisely by alternating current bridges. These bridges are composed of capacitors, inductors, and resistors in a wide variety of combinations. The bridges operate on the principle of the Wheatstone bridge, in which an unknown resistance is balanced against known resistances. The unknown resistance is calculated in terms of the known resistance after the bridge is balanced. One type of capacitance bridge circuit appears in simplified schematic form in figure 15-3. When the bridge is balanced by adjusting the two variable resistors, no a-c voltage is developed across the input of indicator tube V1.



20.344

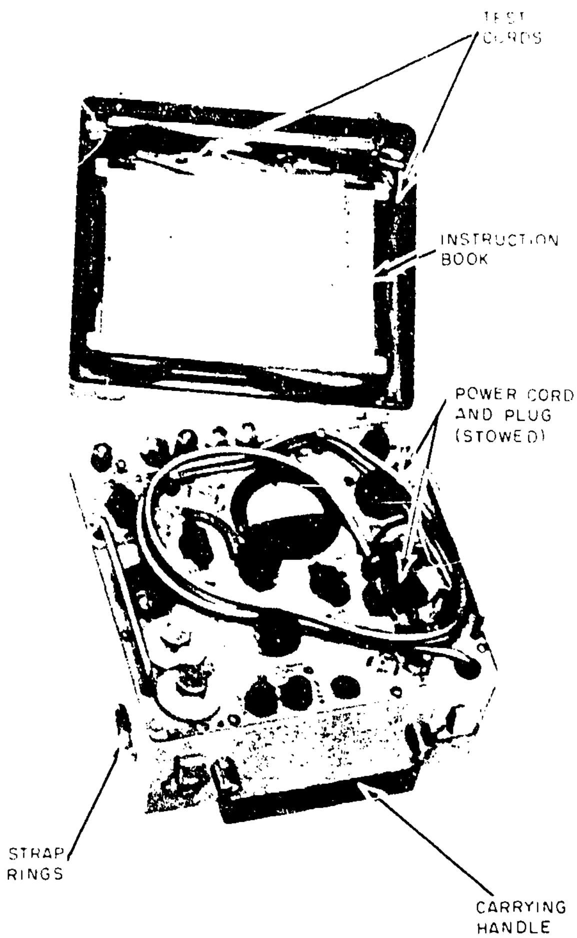
Figure 15-3. -- Simplified schematic of capacity checker.

In the basic Wheatstone bridge circuit using d-c voltages and simple resistances, the balance is obtained when the voltage drops are equal across the ratio arms. In the a-c capacity bridge, it is insufficient to have equality of voltage drops in the ratio arms. The phase angle between current and voltage in the two arms containing the capacitors also must be equal in order to obtain a balance. When a balance is obtained, the current is equal on both sides of the bridge circuit.

The capacitance-inductance-resistance bridge of figure 15-4 not only measures capacitance, resistance, and inductance values, but is also used for special tests, such as the turns ratio of transformers and capacitance quality tests. It is a self-contained instrument, except for a source of line power. It has its own source of 1000-Hz bridge current with a sensitive bridge balance indicator, an adjustable source of direct current for electrolytic capacitor and insulation resistance testing, and a meter with suitable ranges for leakage current tests on electrolytic capacitors.

TRANSFORMER TESTING

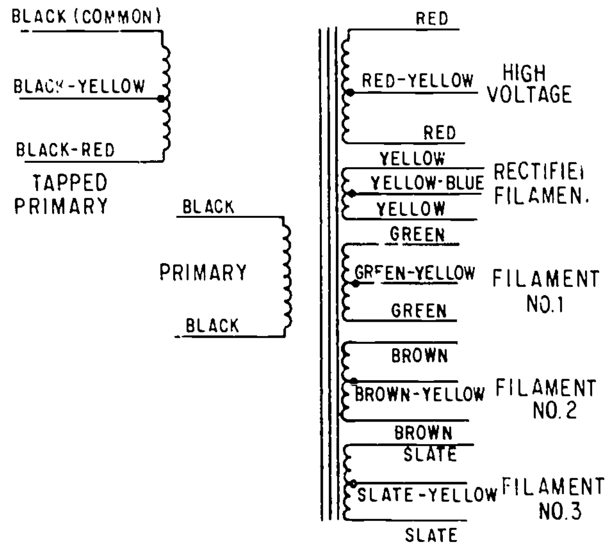
Transformers ordinarily are tested by checking for shorts, measuring resistance of the individual windings, and measuring voltage outputs of each winding. The technical manual for the



20.345
Figure 15-4.—Capacitance-inductance-resistance bridge, type ZM-11/U.

equipment that contains a transformer describes the transformer, specifies the terminals to test for each winding, and tells what each measurement should be. Transformers, of the size used in electronic equipment, usually are color-coded as shown in figure 15-5. In an untapped primary both leads are black. If the primary is tapped, one lead is common and is colored black; the tap lead is black and yellow, and the other lead is black and red.

On the transformer secondary, the high-voltage winding has two red leads, if untapped, or two red leads and a yellow and red lead, if tapped. On the rectifier filament windings, yellow leads are used across the entire winding, and the tap lead is yellow and blue. If there are



20.379(71)
Figure 15-5. — Color coding of small power transformer leads.

other filament windings, they may be green, brown, or slate. The tapped wire is yellow in combination with one of the colors just named; that is, green and yellow, brown and yellow, or slate and yellow.

An easy way to check a suspected malfunctioning transformer is to measure its voltage output. Use a voltmeter to measure across the proper terminals, and compare the reading obtained with the proper voltage given in the manufacturer's manual. If only one reading is in error, then only that winding is at fault. If all readings are in error, the trouble could possibly be a high- or low-input voltage. Consequently, always measure the input voltage as well as the output voltage.

If the voltage measures high or low at any of the output windings, the next step is to measure the resistance of each winding. Make sure the connections to the terminals are disconnected first. Power to the equipment must be secured prior to disconnecting a transformer. Once the leads are free, measure the resistance across each winding with an ohmmeter set to the proper scale. Check each winding carefully, including any center taps. Next, set the ohmmeter to a high scale and test for shorts between windings and between windings and ground.

If no faults are indicated by the voltage or resistance readings, or by the tests for shorts, assume that the transformer is in proper operating condition. Then reconnect it in the circuit.

If a replacement is required, use only the one recommended by the manufacturer's manual. Always test for shorts and check the resistance of a new transformer before installing it in the circuit.

IDENTIFICATION OF CHASSIS WIRING

Standard colors used in chassis wiring for the purpose of circuit identification of the equipment are given below. For electrical and electronic symbols, refer to Graphic Symbols for Electrical and Electronic Diagrams (American National Standards Institute) Y32.2, March 1971.

Circuits	Colors
Grounds, grounded elements and returns	Black
Heaters or filaments, off ground	Brown
Power supply B plus	Red
Screen grids	Orange
Cathodes	Yellow
Control grids	Green
Plates	Blue
Power supply, minus	Violet (Purple)
A-c power lines	Gray
Miscellaneous, above or below ground returns, AVC, and so forth	White

DIODES

A diode is an electrically operated device that has two elements or electrodes. When a voltage of the proper polarity is applied to the electrodes, current flows easily through the diode. Reversing the polarity, however, makes current flow difficult or prevents it altogether.

There are two general classes of diodes: electron tube or solid state. The electrodes of an electron tube diode are enclosed in a glass or metal envelope. A solid state diode is made of two dissimilar metals or two different semiconductors. Depending on the polarity of the applied voltage, current flows or does not flow across the junction formed by the metals or the semiconductors. A semiconductor diode is made of the same materials as those in transistors, usually germanium or silicon.

ELECTRON TUBE DIODES

The major components of an electron tube diode are two polarixed electrodes called anode and cathode. These electrodes are mounted inside an evacuated envelope and fitted into an insulated base. Cathodes are made of materials that emit electrons rapidly and easily; anode materials do not.

When heated, the cathode immediately starts to emit electrons. Although the emission is low, you can measure the potential between the anode and cathode (before an external potential difference is applied between them) by comparing the stable or reference state of the anode material to the electron emission from the cathode material.

At the instant a difference of potential is applied externally between the anode and the cathode, an electric field exists between them. Under the direct influence of the electric field, electrons flow toward the anode, and continue to flow as long as the field exists. The intensity of current flow is directly proportional to the potential difference between the cathode and anode.

Since anode material does not tend to emit electrons, current flow from the anode to cathode does not normally occur. Hence, the electron tube diode acts as a one-way valve or switch.

Should a difference of potential (high in value and reversed in polarity) be placed across an electron tube diode, the dielectric material between anode and cathode may break down, resulting in an excessive quantity of reverse current flow. The breakdown of dielectric material in an electron tube may be closely compared to the breakdown of a capacitor's dielectric. Each is due to excessive electric field strength or extraordinarily high difference of potential across elements of the device. In each case of breakdown there exists some physical means of conducting current between the elements. In capacitors this means is the dielectric; in electron tubes, it is a form of dielectric. Specifically, in electron tubes, it is the evacuated envelope which is not an absolute void or a perfect vacuum.

Operation

Since the evacuated envelope of an electron tube diode is not a perfect vacuum, some matter remains in the existing space. When the cathode is heated, it begins to emit electrons. Upon application of an electric field, these electrons are directed through the so-called vacuum to the anode, through the source, and back to the cathode.

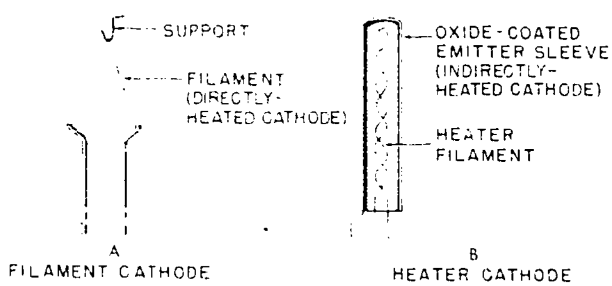
In some cases electron tube diodes are constructed without a means for heating the cathode. Called cold cathode diodes, they work on the principle that a difference of potential placed across the anode and cathode creates an electric field. Since cathode material emits electrons, they are started on their path to the anode. These diodes are filled with an inert gas, such as neon, argon, krypton, or xenon. When electrons flow in this gas, it becomes ionized, or electrically charged. As current flow through an inert gas diode increases, more energy is dissipated in ionizing the gas. Within the limits established by the quantity and type of gas, the diode will maintain a constant voltage drop across its elements, though current flow through them varies.

Since some energy is dissipated in the form of heat while a cold cathode electron tube operates, the cathode temperature does rise. Therefore, the term "cold cathode" is not completely accurate and only indicates that the electron tube lacks a cathode heating element.

Construction

Cathodes are heated in one of two ways—directly or indirectly. In a directly heated cathode, the current that furnishes the heat flows directly through the emitting material. In an indirectly heated cathode, the heating current flows through a heating filament and transfers heat to the emitting material (cathode). Figure 15-6 illustrates the construction and methods of heating the two types of cathodes.

The directly heated cathode, commonly called a filament, is fairly efficient and can emit large amounts of energy. However, due to the small mass of the filament wire, the filament temperature fluctuates with changes in current flow. If an a-c source is used to heat the filament, an undesired hum may be introduced into the circuit. The hum is especially evident in low level signal circuits.



13.21
Figure 15-6.—Methods of heating the cathodes of electron tubes.

A relatively constant rate of emission under mildly fluctuating current conditions may be obtained with an indirectly heated cathode. This type of cathode is in the form of a cylinder; in its center is a twisted, electrically insulated wire, called the heater. The cathode is maintained at the correct temperature by heat radiated from the heater. The emitting material in this type of cathode remains at a relatively constant temperature, even with an a-c heater. Figure 15-7 illustrates the schematic symbols for directly and indirectly heated cathodes.

The cathode is normally placed in the center of the tube structure, and is surrounded by the anode, also called the plate. Figure 15-8 shows cutaway views of two types of diodes. One has a directly heated cathode or filament, the other

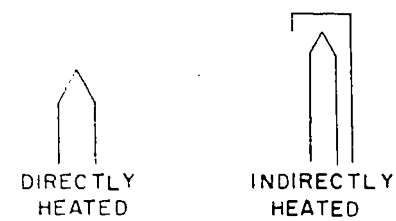


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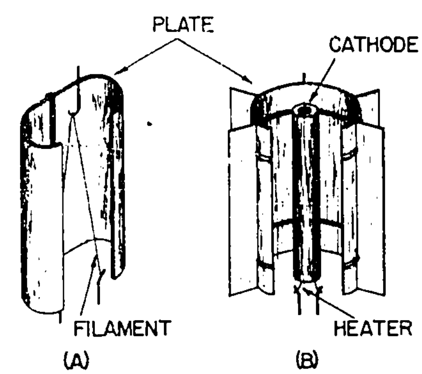
Figure 15-7.—Schematic symbols for directly and indirectly heated cathodes.



179.142
Figure 15-8.—Cutaway views of directly and indirectly heated diodes.

an indirectly heated cathode. (The heater of the indirectly heated cathode does not count as an element of the diode.) The plate material, besides not tending to emit electrons, must be able to dissipate the heat generated by electrons striking the plate.

The schematic symbols for diode tubes are shown in figure 15-9. In some cases, two or more diodes are included in the same envelope to conserve space. A tube which contains two plates and one or two cathodes is called a duo-diode or twin diode. Figure 15-10 illustrates the construction and schematic symbols of duo-diode electron tubes.

As a rule, electron tubes are not expected to last as long as resistors, capacitors, or other circuit components. This is due, in large part, to wearing out or breaking down of the filament or heater. To make it easy to remove and replace a tube, the base of the tube (figure 15-10) is constructed in the form of a plug, which fits into a socket on the chassis. The electrical connections between the tube elements and the circuit are completed through the plug terminals, called pins.

There are various types of tube bases, containing different numbers and sizes of pins. Each type of tube base has a guide or key to prevent the tube from being plugged into the socket improperly. To make circuit tracing easy, the tube pins are assigned numbers. At the BOTTOM of the tube or socket, the pins are numbered in a clockwise direction, beginning with No. 1 at the key or guide. The pin numbering systems for several types of tubes are shown in figure 15-11.

Ratings

Each diode has certain voltage, current, and power ratings. By definition, a rating is the limiting value which must not be exceeded to prevent permanent damage to a device, such

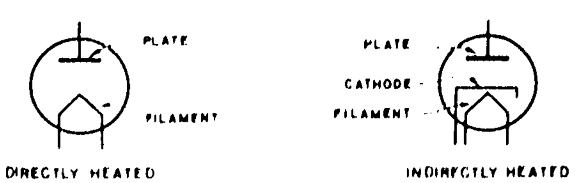


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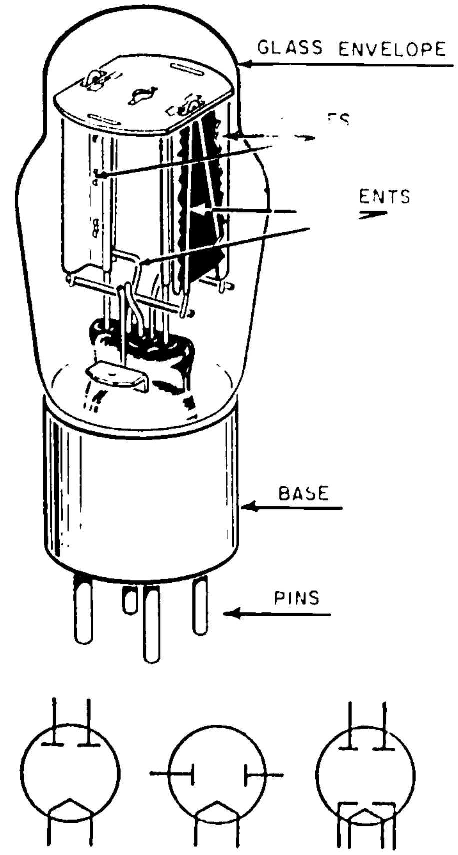
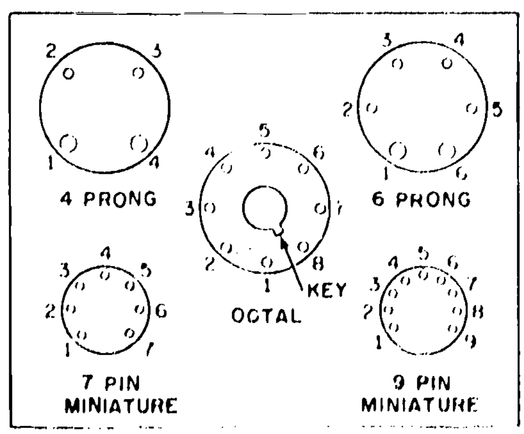
Figure 15-9.—Schematic symbols used to represent diode tubes.



4.140(20C)
Figure 15-10.—Construction and schematic symbols of duo-diodes.



4.141
Figure 15-11.—Pin numbering systems for several tube types.

as the diode. The filament or heater voltage and current values must be correct for proper operation of an electron tube. If heater current is too low, the cathode will not emit enough electrons. Too much heater or filament current may reduce the life of the tube or destroy the heater or filament.

Other important diode electron tube ratings are:

PLATE DISSIPATION — the maximum average power, in the form of heat, which the plate may safely dissipate.

MAXIMUM AVERAGE CURRENT — the highest average plate current which may be handled continuously, based on the tube's permissible plate dissipation.

MAXIMUM PEAK PLATE CURRENT — the highest instantaneous plate current that a tube can safely carry in the direction of normal current flow.

PEAK INVERSE VOLTAGE (PIV) — the highest instantaneous plate voltage which the tube can withstand, acting in a direction opposite to that in which the tube is designed to pass current (plate negative — cathode positive).

DIODE RECTIFIERS

The electron tube diode is a rectifier; that is, a device for converting alternating current to direct current. Alternating current constantly reverses direction as it flows through a wire. Each time the current reverses direction, it alternately carries electrons to the anode, making it negative, and away from the anode, making it positive. The anode attracts electrons from the cathode only during the periods when it is positive.

Figure 15-12, view A, shows a diode in a half-wave rectifier circuit or a circuit that rectifies only one-half of the a-c cycle. The transformer steps down the voltage to provide filament voltage for the diode and heater voltage. Alternating current flows through the secondary winding; the output of the circuit is pulsating direct current. When the plate of the diode in this circuit is positive, it attracts electrons from the filament and current flows through the tube. Electrons travel from the plate through the transformer and return to the filament by way of the load resistor. The filament then becomes the positive terminal for the power supply; the transformer lead becomes the negative terminal. As the alternating current changes direction of electron flow, the plate becomes negative and no current flows through the diode. Since current flows through the diode during half of the a-c cycle only, a pulsating d-c is produced. This current can be smoothed out by means of a filter which enables current to flow when the rectifier is not operating.

For a more constant flow of current, both halves of the a-c cycle are rectified. In this case, you have a full-wave rectifying circuit that has two diodes or one twin diode. The high-voltage secondary of the transformer is tapped in the center. One plate goes to one side of the secondary; the other plate to the opposite side of the secondary. (See figure 15-12, view B.)

When the plate of diode V1 is positive, it pulls electrons from the filament and current

20.37:.40.1

Figure 15-12. — Electron tube rectifier circuits.

flows through V1 to the plate and out through the center tap of the transformer. As the alternating current starts to flow in the other direction, the plate of diode V1 becomes negative and that of diode V2 becomes positive. Electrons are now attracted to the plate of V2. Current flows through V2 to the plate and out through the center tap of the transformer. Electron flow through the center tap is always in the same direction. Both halves of the a-c cycle are rectified and current flows all the time.

SOLID STATE DIODES

Conductors are substances made up of atoms whose outer-orbit electrons are loosely bound. At ordinary room temperature, enough heat energy is applied to the atoms to permit large numbers of these electrons to be liberated (free electrons), and to drift aimlessly about from one atom to another. If a voltage is applied to the end of a conductor, free electrons will stream to the positive side as other electrons enter from the negative end. It is in this way that current flows through a conductor. As carriers of electricity, the electrons move from the negative to the positive side of the conductor.

In an insulator, on the other hand, the outer-orbit electrons are tightly bound and there are few free electrons. As a result, little current will flow when a voltage is applied to the end of the insulator. If the voltage is high enough to rupture the insulator, however, current will flow, which may be in the form of an arc.

There are solid substances, known as semiconductors, whose outer-orbit electrons are not loosely bound, as in conductors, or tightly bound, as in insulators. Two examples are germanium and silicon. If a voltage is applied to a semiconductor, current will flow, but not as readily as in a conductor.

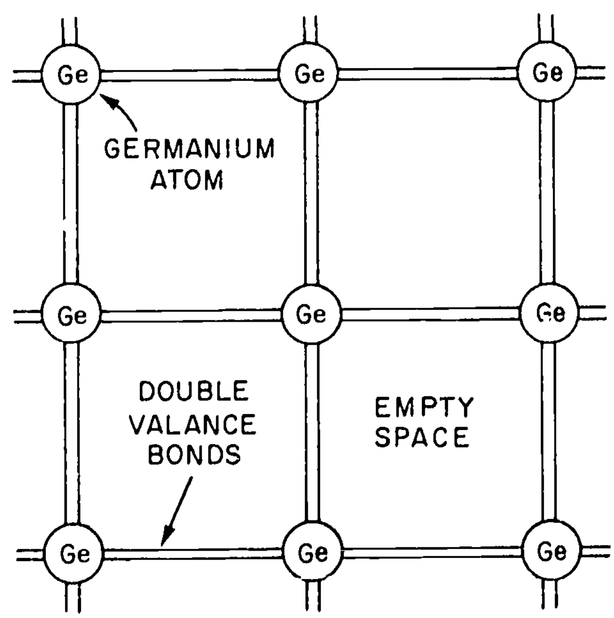
Atomic Theory

The germanium atom has a nucleus of 32 protons and 32 orbiting electrons arranged in four concentric shells or orbits. The three shells closest to the nucleus are completely filled with 28 electrons, the outermost shell containing the remaining 4 electrons. The electrons of the outermost shell are called the valence electrons; they determine the chemical and electrical properties of the atom.

Since the outermost electrons are loosely bound to the nucleus at ordinary room temperature, many of them escape and wander as free electrons. Where an electron escapes from its atom, a hole is left in its place. The loss of the electron and the appearance of the hole converts the neutral atom into a positive ion. Thus, the hole is said to have a positive charge that is equal and opposite to the negative charge of the free electron.

When a hole appears in an atom, an electron from a neighboring atom may move in to fill this hole, leaving a hole in its place. Thus, a hole moves from the first atom to the second atom just as a free electron moves, except that the hole carries a positive charge instead of a negative charge. A rise in temperature or the presence of an electric field can force free electrons to move toward a positive pole. As free electrons move toward the positive pole, holes move toward the negative pole.

In a crystal of pure germanium, the atoms arrange themselves in a geometric pattern, each atom being relatively far from its neighbor. Though the crystal is a three-dimensional structure, figure 15-13 shows two dimensions only. The two parallel lines linking each germanium atom (Ge) to its neighbor represents a double-valence bond made up of one valence electron from each atom. Each germanium atom is linked up with four other atoms, thus accounting for its



73.372

Figure 15-13.— Germanium crystal.

four valence electrons. When an electron escapes from one of the double valence bonds, it leaves a single-valence bond and a hole.

The number of free electrons in a germanium crystal can be increased by adding a small amount of an impurity, such as arsenic. An atom of arsenic has five valence electrons. It replaces one of the germanium atoms in the crystal, combining with its four neighbors and leaving one of its electrons free, as shown in figure 15-14, view A. Such a germanium crystal is called a N-(negative) type.

Similarly, the number of holes in a germanium crystal can be increased by adding a small amount of an impurity, such as boron. A boron atom has three valence electrons. When it replaces one of the germanium atoms in the crystal, the boron atom forms double-valence bonds with three of its germanium neighbors. With its fourth neighbor, it forms a single-valence bond and leaves a hole for the missing electron as shown in figure 15-14, view B. Such a germanium crystal is called a P-(positive) type.

The Crystal Diode

In view A of figure 15-15, a P-type germanium crystal joins an N-type germanium crystal to form a P-N junction diode. Each N-P type of crystal contains a number of free electrons (indicated by -) and an equal number of holes (indicated by +). The N-type crystal, however, has many more free electrons introduced by the five-valence impurity; the P-type crystal, on the other hand, has many more holes introduced by the three-valence impurity. With a battery connected as shown in figure 15-15, view B (positive lead connected to the P-type crystal and negative lead to the N-type crystal) all the free electrons tend to move toward the positive lead and all the holes toward the negative lead.

Thus most of the free electrons and holes tend to move toward the junction between the two crystals. Because opposite charges attract, the electrons and holes rush toward each other and recombine as a free electron drops into a hole. The effect of the applied voltage is to produce more free electrons in the N-type crystal and more holes in the P-type crystal. Hence, there is a continuous movement of electrons and holes through the crystals, creating a relatively high current flow through the entire circuit as indicated by the arrows. When applied as shown in figure 15-15, view A, the voltage is said to be in the forward direction.

Now suppose the battery is reversed as shown in figure 15-15, view C. Again the free electrons

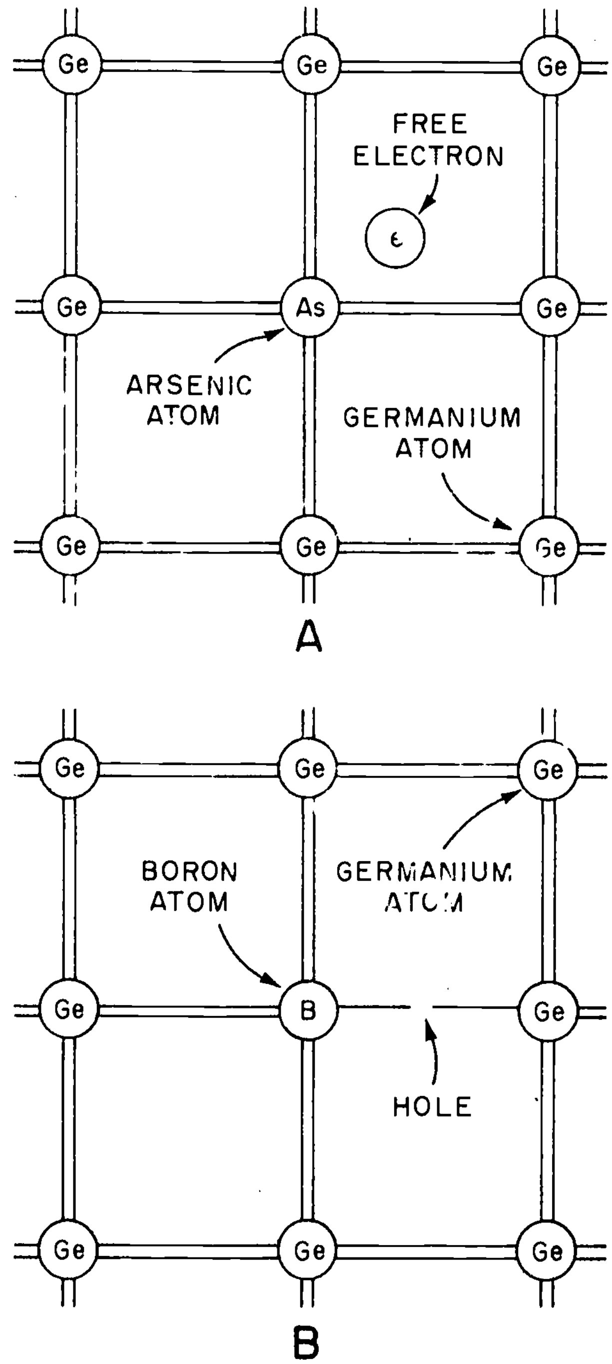


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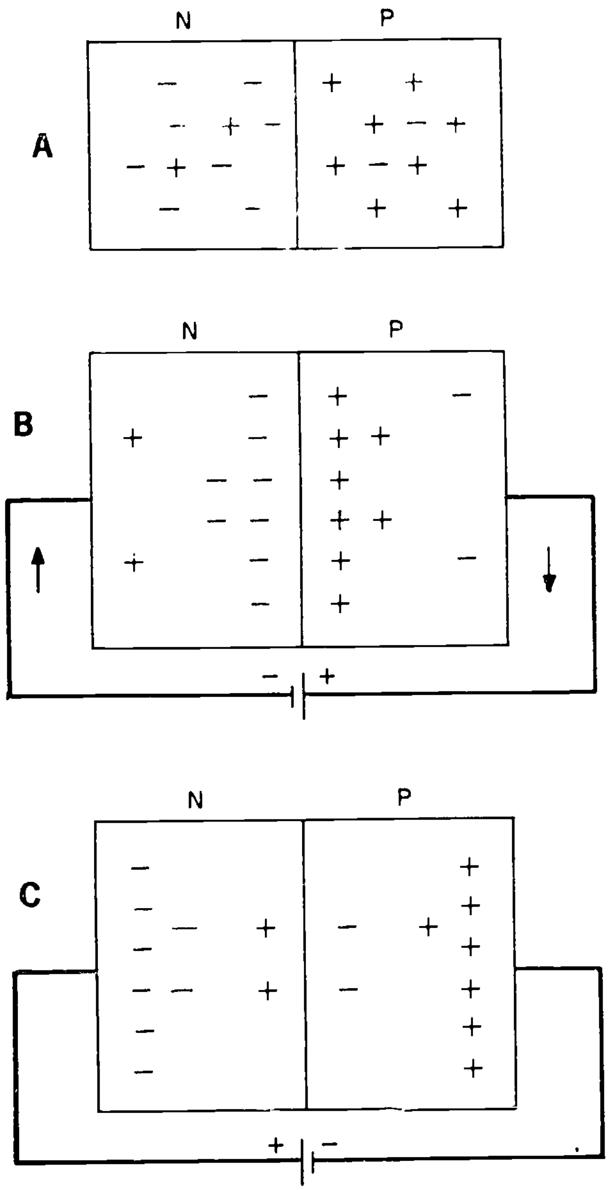
Figure 15-14.—(A) Structure of N-type crystal; (B) Structure of P-type crystal.

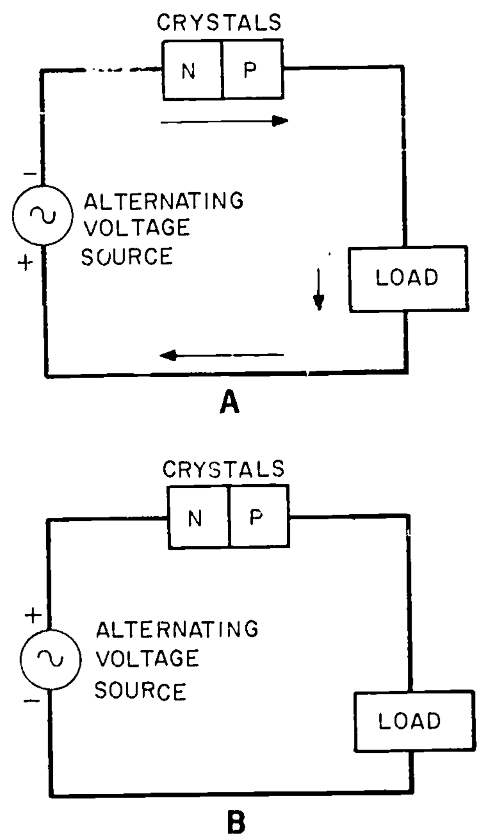
flow toward the positive lead and the holes flow toward the negative lead. But since there are relatively few electrons and holes at the junction of the crystal, the flow of current across the junction is small and so is the current flow in the circuit. When applied as shown in figure 15-15, view C, the voltage is said to be in the reverse, or nonconducting, direction.

If a source of alternating current is applied to the crystals connected in series with a load, the voltage for one-half cycle will be in the forward direction (figure 15-16, view A) and current will flow through the circuit. During the next half-cycle the voltage will be in the reverse direction (figure 15-16, view B) and no current will flow. This is how an N-P junction diode rectifies alternating current just as the electron-tube diode does.



73.374

Figure 15-15.—(A) Distribution of free electrons and holes when N-type and P-type crystals are joined together; (B) Distribution of free electrons and holes when voltage is applied in forward direction; (C) Distribution of free electrons and holes when voltage is applied in reverse direction.



73.375

Figure 15-16.—The junction diode as a rectifier; (A) Voltage applied in forward direction. Arrows indicate direction of current flow; (B) Voltage applied in reverse direction. There is no current flow.

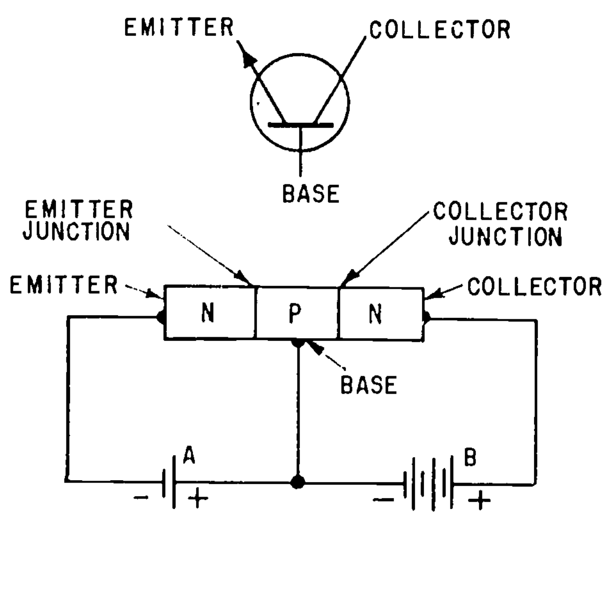
TRANSISTORS

In figure 15-17, a thin P-type crystal is sandwiched between two N-type crystals. The emitter terminal is on the left-hand N-type crystal, the collector terminal on the other N-type crystal, and the base terminal on the P-type crystal. The junction between the left-hand N-type crystal and the P-type crystal is the emitter junction; the one between the right-hand N-type crystal and the P-type crystal is the collector junction. The entire sandwich with its terminals is a junction transistor. The junction transistor consists of a single unit with the three distinct regions or layers being doped with controlled amounts of impurities. The schematic symbol for a transistor is also shown in figure 15-17.

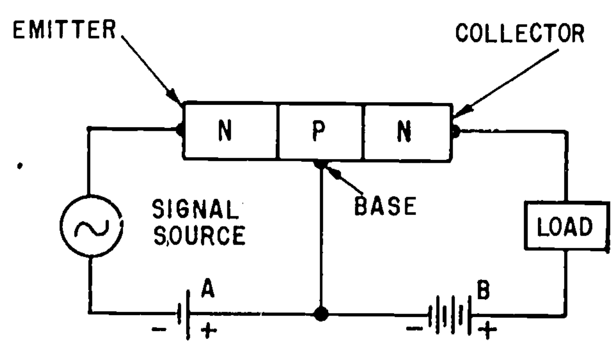
Note that the voltage from battery A is applied in the forward direction, relative to the emitter junction. Thus the impedance of this junction is low. On the other hand, the voltage of battery B is applied in the reverse direction relative to the collector junction. Therefore its impedance is high. As a result, electrons flow readily from the emitter to the base, where some of them combine with the holes in the P-type crystal. If this crystal were made thin enough, nearly all the electrons entering the emitter would be attracted to the positive collector terminal and flow through the external collector circuit to battery B. That is, a flow of current in the emitter circuit produces almost the same flow of current in the collector circuit. However, since the impedance (Z) of the emitter circuit is low and that of the collector circuit is high, the power ($I^2 \times Z$) is greater in the collector circuit than in the emitter circuit. This explains how the junction transistor acts as a power amplifier — a device that increases the input signal without changing its characteristics a great deal. To indicate the obtainable increase in power, or gain (Ic), the impedance of the emitter circuit may be as low as 25 ohms, whereas the impedance of the collector circuit may be several megohms.

The basic amplifying circuit is shown in figure 15-18. Assume that the incoming signal is in the form of an alternating voltage. When connected into the emitter circuit, the signal source alternately adds to or subtracts from the voltage of battery A. Hence, the current flow through the low-impedance emitter circuit is respectively larger or smaller. Accordingly, a larger or smaller current flows through the high-impedance collector circuit (which contains the load in series). As explained previously, a low power input to the emitter circuit produces a large power output at the load in the collector circuit. The transistor is called an N-P-N junction transistor because of the arrangement of the N- and P-type crystals.

It is possible to form a P-N-P junction transistor by sandwiching the N-type crystal between two P-type crystals. Since the relative



73.375
Figure 15-17. — Basic junction transistor circuit.



73.376
Figure 15-18. — N-P-N junction transistor used as amplifier.

positions of the crystals are reversed in the P-N-P transistor, the polarities of the battery must be reversed; also, instead of electrons, holes flow from the emitter to the negatively charged collector terminal. Figure 15-19 shows the differences in the schematic symbols for the N-P-N and P-N-P transistors.

Transistors can carry out many of the functions of electron tubes. Transistors have certain advantages in that they consume less power, last longer, can take rough handling, and can be built much smaller and more compactly. Also, transistors have no filaments, so practically no heat is produced.

TRANSISTOR LEAD IDENTIFICATION

You must be able to identify the leads or terminals of a transistor before it is connected into a circuit. As there is no standard method

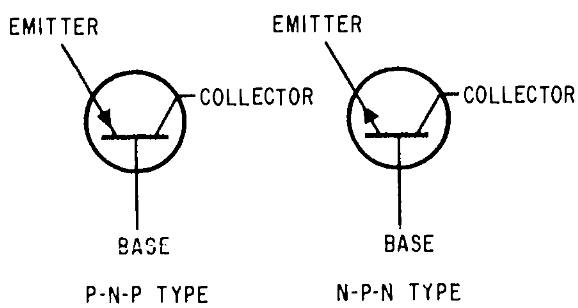


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Figure 15-19.—Schematic diagrams of transistor types.

of identifying transistor leads or terminals, it is quite possible to mistake one lead for another.

In figure 15-20, the bases of four pairs of transistors are shown. Each pair, while similar in appearance, has different elements connected to the leads. For the top transistor of the left-hand pair, the leads are emitter, base, collector, reading from left to right; for the bottom transistor of this pair, the leads are emitter, collector, and base. If one of these transistors was connected into a circuit as a replacement for the other, the circuit would not function properly or the transistor might be destroyed. The same general results apply for the other pairs of transistors. Note that in the right-hand pair, the cases can and are used for emitter or collector connections.

In replacing one transistor with another, do not rely on shape. Be sure the leads are where they should be and that the transistor chosen as a replacement is suitable. If there is any doubt, consult the equipment manual or a transistor manual showing the specifications for the transistor being used.

CIRCUITRY

There are three basic ways of connecting a transistor in a circuit: common or grounded base (fig. 15-21), common or grounded emitter (fig 15-22), and common or grounded collector (fig 15-23). The connections differ in whether the base, emitter, or collector is part of (common to) both the emitter and collector circuits. Regardless of the connection, the output signal is taken from across the load.

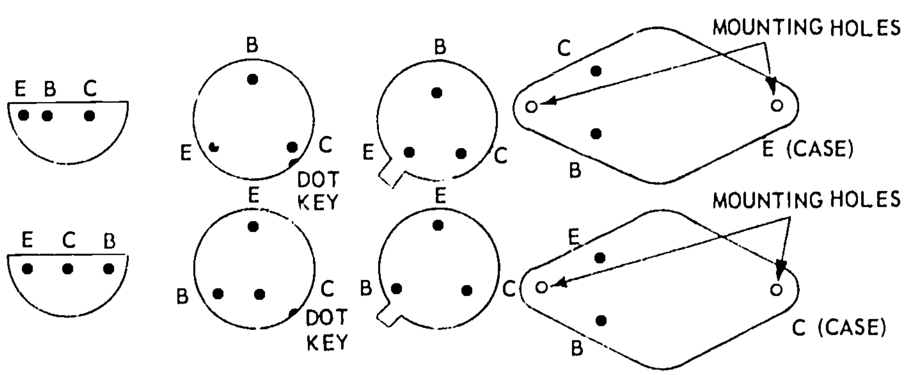

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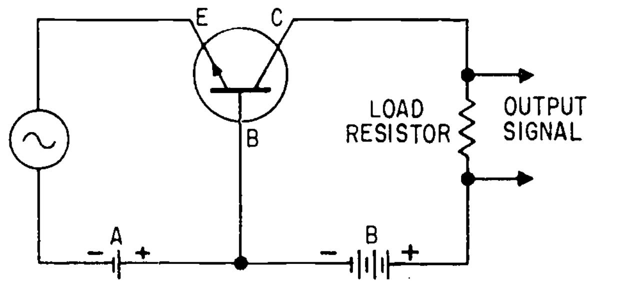
Figure 15-20.—Bottom view of some common transistor cases.



73.378
Figure 15-21.—Common base amplifier circuit.

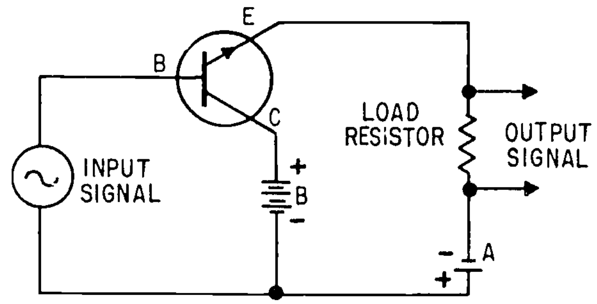


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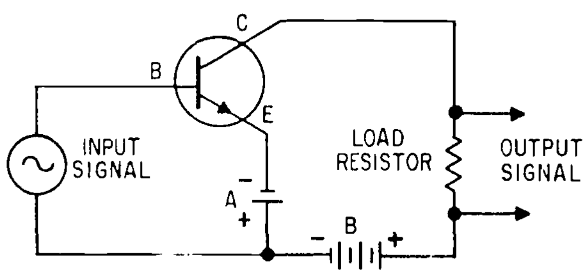
Figure 15-23.—Common collector amplifier circuit.



73.379
Figure 15-22.—Common emitter amplifier circuit.

Table 15-2.—Transistor amplifier comparison chart

AMPLIFIER TYPE	COMMON BASE	COMMON EMITTER	COMMON COLLECTOR
INPUT/OUTPUT PHASE RELATIONSHIP	0°	180°	0°
VOLTAGE GAIN	HIGH	MEDIUM	LOW
CURRENT GAIN	LOW (α)	MEDIUM(β)	HIGH (γ)
POWER GAIN	LOW	HIGH	MEDIUM
INPUT IMPEDANCE	LOW	MEDIUM	HIGH
OUTPUT IMPEDANCE	HIGH	MEDIUM	LOW

179.94

Note that the symbols indicate the use of an N-P-N transistor in each circuit. With a P-N-P transistor, reverse the polarities of the battery. Each basic circuit has its own measureable properties, such as impedance or gain under given operating conditions. Which circuit is to be used depends upon the design requirements of a particular amplifier.

Table 15-2 compares characteristics of the three basic circuits.

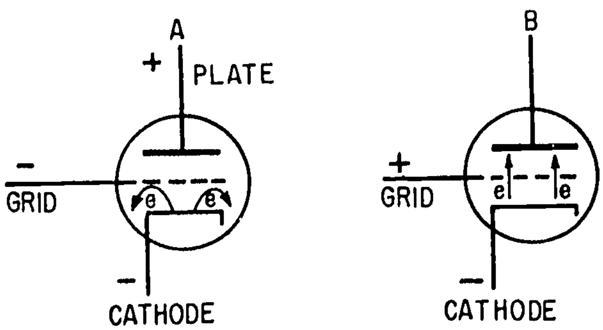
ELECTRON TUBE TRIODES

Another kind of electron tube, the triode, is widely used as an amplifier of signals. As its name suggests, the triode has three elements: cathode, plate, and control grid. This grid is usually a metal screen or coil of fine wire inserted between the plate and cathode, but closer to the cathode. As long as the grid is uncharged, most of the electrons flowing from the cathode to the plate are free to move through the openings of the grid. Placing a negative charge on the grid has a repelling effect on the stream of electrons passing through the grid, and tends to reduce the number of electrons that do. Increase the negative charge, and fewer electrons pass through the grid. When the negative charge on the grid is made large enough, electrons do not pass between the cathode and plate (fig. 15-24, view A.)

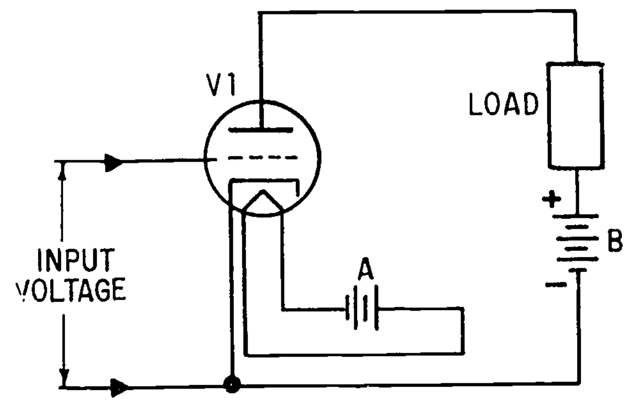
However, a positive charge placed on the grid attracts the electrons. Increase the positive charge, and more electrons are attracted to the grid. Some electrons strike the wire of the grid, but most of them flow through to strike the plate (fig. 15-24, view B) since the grid is mainly open space. The grid, then, regulates the flow of electrons much as a venetian blind controls the amount of light that enters a room. Depending on the voltage applied to the grid, more or less plate current flows through it.

Of course, you can vary the plate current flow by making the plate more or less positive. But since the grid is closer to the cathode (the source of electrons), a smaller variation in the charge of the grid has the same effect on the plate current as a larger variation on the charge of the plate. Weak signals change the charge and voltage on the grid, and so produce big changes in the plate current. In this way, the triode amplifies the weak signals.

The triode of figure 15-25 has three distinct circuits: the FILAMENT circuit consisting of the heater and A battery or other source of heating current; the PLATE, or output, circuit consisting of the cathode, the electron flow from cathode to plate within the tube, the plate, the load, and the B battery (commonly known as B+); and the GRID, or input, circuit consisting of the cathode control grid, and the source of input voltage.



73.381
Figure 15-24.—Effect of the grid in a triode.



73.382
Figure 15-25.—Basic triode circuits.

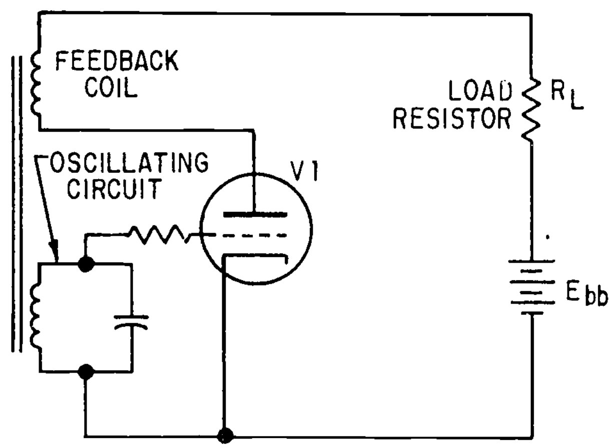
To demonstrate the use of a triode as an amplifier, assume that a small varying voltage is applied to the grid circuit. Since the charge on the grid varies with the applied voltage, the plate current flowing through the tube varies accordingly, causing similar variations in the current flowing through the load. If the load resistance is high, the resulting voltage drop (I x R) across the load is also high and varies directly with the input voltage. Therefore, a small varying voltage applied to the input circuit of the triode produces a large varying voltage in the output circuit.

The triode can be compared to the transistor. The cathode operates like the emitter, the plate like the collector, and the grid like the base.

OSCILLATORS

An amplifier, such as the triode, can also be used as an oscillator—an electronic device that produces a constant signal of a certain frequency. As an oscillator, the triode feeds back to itself part of the signal it puts out. The feedback produces signals that oscillate, or vibrate, at a certain frequency. The resistance inductance, and capacitance of the input circuit enable the triode to amplify only the signals that have the desired frequency. This is commonly known as the resonant frequency.

To demonstrate the use of a triode as an oscillator, connect the input circuit of the tube as shown in figure 15-26. This places an a-c voltage on the grid of the triode. The resulting plate current satisfies the needs of the load



73.383
Figure 15-26.—Oscillator, triode, and feedback circuit.

with enough left over to feed back to the oscillating circuit to compensate for its losses, and to remain in oscillation. The plate current feeds back through the so-called feedback coil that is coupled (connected) to the inductor of the oscillating circuit. In this way the feedback coil serves as the primary winding of a transformer; the inductor of the oscillating circuit as the secondary winding.

When proper values are selected for the inductor and the capacitor of an oscillating circuit, frequencies in millions, even billions, of hertz (cycles per second) can be generated.

Example: Assume that the value of an inductor is 20 microhenrys and that of a capacitor is 80 picofarads. Determine the frequency by using the formula:

$$\text{Frequency} = \frac{1}{2\pi \sqrt{L \times C}}$$

where $L = 20\,\mu h = 2 \times 10^{-5}$ henrys and $C = 80\,pF = 8 \times 10^{-11}$ farads

$$\text{Frequency} = \frac{1}{2\pi\sqrt{2 \times 10^{-5} \times 8 \times 10^{-11}}}$$

$$= \frac{1}{2\pi\sqrt{16 \times 10^{-16}}} = \frac{1}{2\pi \times 4 \times 10^{-8}}$$

$$= \frac{10^8}{8\pi} = 4{,}000{,}000 \text{ Hz (approximately)}$$

MULTIELEMENT ELECTRON TUBES

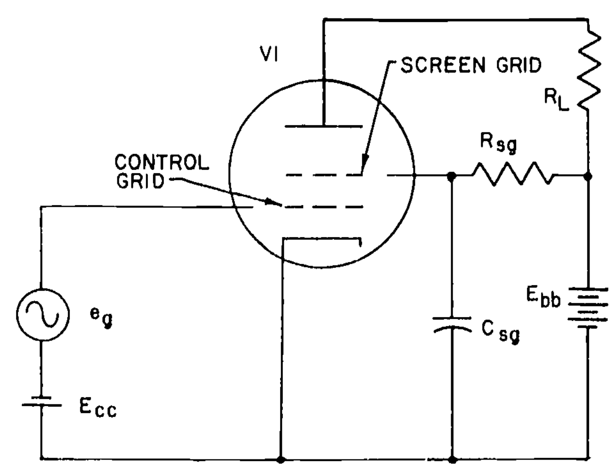
Several elements other than the cathode, plate, and control grid are inserted in some electron tubes for special purposes. Tubes having more than these three elements are known as multielement tubes. A tetrode, for example, is a four-element tube. Its extra element is another grid called the screen grid. Another electron tube, the pentode, has three grids—a control grid, a screen grid, and a suppressor grid. All multielement tubes have special uses and some require special tube sockets. All of them, however, work on the same basic principle as the triode.

TETRODES

The tetrode is an amplifying tube. Its fourth element, the screen grid, is mounted between the control grid and the plate. (See figure 15-27.) The screen grid has a positive charge with respect to the cathode; it attracts a steady flow of electrons from the cathode. Because the mesh of the screen grid is relatively large, most of the attracted electrons pass through it and, in turn, are attracted by the plate. Thus the screen grid supplies an electrostatic force that pulls electrons from the cathode t the plate.

As long as the plate voltage is h ·er than the effective screen grid-to-cathode voltage, plate current in a tetrode depends mostly on screen-grid voltage and little on plate voltage. Thus a tetrode is better as an amplifier than a triode. Also, the screen grid reduces capacitance by serving as an electrostatic shield between the control grid and the plate. Reducing grid-to-plate capacitance results in high amplification and keeps the amplifier from oscillating.

Figure 15-27 illustrates a basic tetrode amplifier circuit. R_{sg} is the screen-dropping resistor



73.384
Figure 15-27.—Basic tetrode amplifier circuit.

that maintains the screen-grid operating voltage; C_{sg} is the screen-bypass capacitor that maintains the screen grid at a constant voltage.

PENTODES

The pentode's fifth element, or suppressor grid, is located between the screen grid and the plate. The suppressor grid is connected internally or externally to the cathode. Figure 15-28 shows the internal connection.

Electrons flowing from the cathode to the plate cause the plate to give off electrons by secondary emission, which means freeing of electrons by bombardin· ιem with other electrons. Being negative \ respect to the plate, the suppressor grid keeps the secondary emission electrons from leaving the plate and interfering with the operation of the tube. The main electron stream is hardly affected by the presence of the suppressor grid.

Since the suppressor grid is negative with respect to the screen grid or plate, it does not draw current. Therefore the relationships of voltages and currents are essentially the same as those in the tetrode.

The pentode has replaced the tetrode in radio frequency (RF) amplifiers because it permits a somewhat higher amplification in moderate values of plate potential. In some special-purpose pentodes, the suppressor grid serves as a signal grid.

METHODS OF BIASING

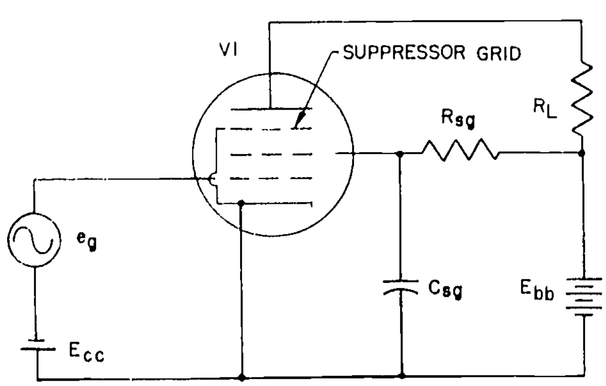
In some amplifier circuits, d-c voltage in the grid circuit is supplied from a fixed source, such as a battery or other power supply (fig. 15-29). This type of voltage is known as fixed bias. In another type, called self-bias, voltage is developed across a resistor by tube current or input signal. Cathode bias and grid-leak bias are forms of self-bias.

CATHODE BIAS

This form of self-bias is illustrated in figure 15-30. When the cathode of an electron tube is biased positively with respect to the grid, the electron tube operates exactly as though an equivalent negative bias is applied to the grid. Since current flow with an electron tube is from the cathode to the plate, a resistor can be inserted in the cathode line to procuce a voltage drop (cathode bias) as long as the plate current flows continuously. Since cathode current always flows in the same direction, the voltage drop remains more positive at the cathode. Thus, plate current flow within the electron tube itself produces a positive cathode bias.

GRID-LEAK BIAS

Grid-leak bias is obtained by allowing grid current flow, produced by an a-c signal input, to charge a resistance-capacitance (RC) network in the grid-cathode circuit. Two basic circuits



73.385
Figure 15-28.—Basic pentode amplifier circuit.

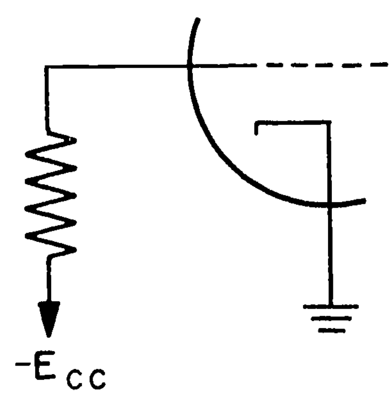


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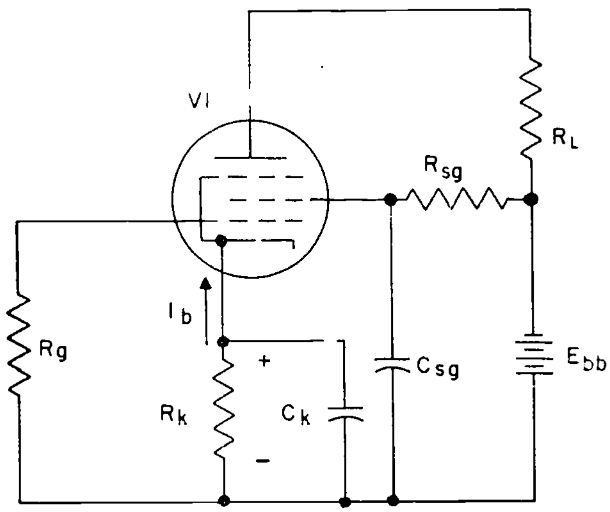
Figure 15-29.—Schematic of fixed bias.



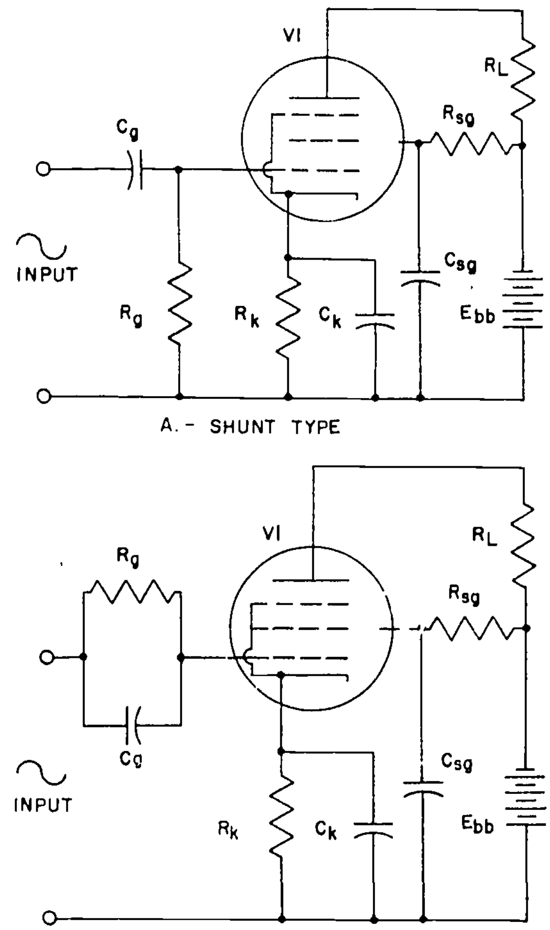
73.387
Figure 15-30.—Obtaining cathode bias.

are used to develop this form of self-bias: shunt and series (fig. 15-31). The methods of developing grid voltage in these circuits are similar, but the physical connections of the network components are different.

The grid-cathode circuit is used in both basic circuits as a diode rectifier to develop a d-c voltage proportional to the positive peak input (driving) signal amplitude. A grid-leak capacitor (Ck) operates as a coupling capacitor to apply the input signal to the grid. On the positive input signal excursions, the grid is driven positive, causing grid current to flow between grid and cathode and through a grid-leak resistor (Rg). The result is to produce a d-c voltage across Rg which is polarized negatively at the grid.

COUPLING METHODS

Usually more than one amplifier is needed to increase the amplitude of a feeble input signal to the required output valve. The amplifiers are cascaded, that is, connected in series so the output of one goes to the input of another. Cascaded amplifier stages are connected (coupled) by resistance-capacitance (RC) networks, impedance (LCR) networks, transformers, or direct coupling. Though some coupling networks respond to frequency better than others, the basic method of

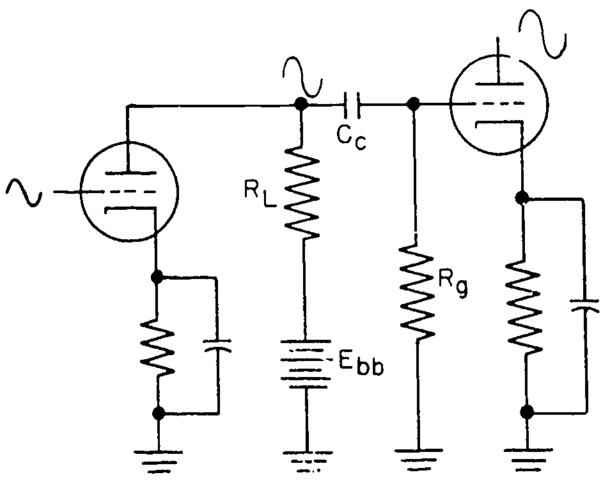


73.388
Figure 15-31.—Grid-leak bias connections.

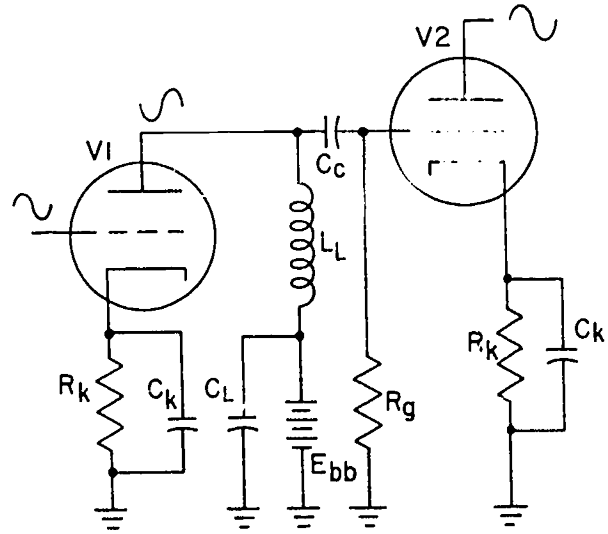
coupling is the same whether the amplifiers are used singly (as input or output coupling devices) or in cascade.

RC COUPLING

RC coupling involves the use of two resistors and a capacitor, as shown in figure 15-32. Because of their rather high frequency response, small size, and economy of operation, RC-coupled amplifiers are nearly always used where voltage amplification is desired with little or no power output. Since the plate resistor (R_L) and grid resistor (Rg) are not frequency responsive, the overall frequency response is limited basically by the capacitive reactance of the coupling capacitor (C_c) between the plate and grid circuits, plus the effect of shunt wiring and cathode-to-ground capacitances across the network. With



73.389
Figure 15-32.—RC-coupled amplifier.



73.390
Figure 15-33.—Impedance-coupled amplifier.

direct current (zero frequency) the coupling capacitor separates or blocks the plate voltage of the driving stage from the grid bias of the driven stage, so that bias or plate or element voltages are not affected between stages. Note that, with respect to alternating current, the tubes are in parallel with R_L.

In the conventional RC amplifier, signal voltage variations on the grid produce plate current variations through the plate resistor, and the resulting voltage developed across it represents an amplified replica of the input signal but 180 degrees out of phase. The amplified signal is coupled through capacitor C_c and applied to the grid of the next stage across the grid resistor. The same cycle of operation is repeated for each stage of the cascaded amplifier.

RC-coupled amplifiers generally have a low gain, or ratio of signal output to signal input; therefore, they are seldom used in RF amplifiers. They have special applications, such as test equipment.

IMPEDANCE COUPLING

When an inductor is substituted for the plate load resistor in an RC-coupled circuit, an impedance-coupled circuit results (fig. 5-33). The impedance coupled and RC-coupled circuits operate in the same manner as far as C_c and Rg are concerned; the basic difference lies in the effect of plate impedance. By using an impedance in the plate circuit, there is a smaller voltage drop for a given voltage supply. Therefore, a lower supply source will provide the same effective plate voltage, smaller loss in power (I^2R), and better overall efficiency. Low frequency response depends on obtaining a high inductive reactance in the plate circuit and requires a large number of turns for good low-frequency response. The distributed capacitance associated with a winding of many turns produces a large shunting capacitive reactance with a consequent drop in high-frequency response. Since the impedance of the plate circuit varies with frequency, the response is not as uniform as that of the RC coupling.

The impedance-coupling circuit is used where a limited response over a relatively narrow band of frequencies is required. As a result, impedance coupling is usually found in amplifier stages, such as intermediate-frequency or radio-frequency stages. Its use in audio frequency stages has generally been discontinued in favor of the RC or transformer coupling, except for special designs.

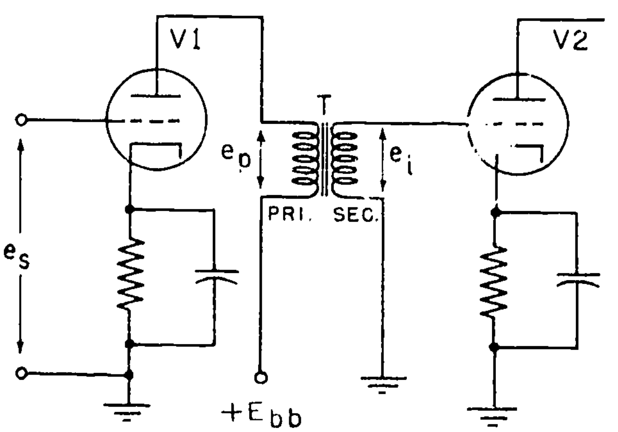
TRANSFORMER COUPLING

In transformer coupling (fig. 15-34), the primary of a transformer is connected as the plate load, and the secondary provides the output signal, either to the next stage or an output device. Frequency response, gain, and output become more difficult to predict because they depend primarily on the transformer design. Basically, transformer coupling provides additional gain, through the use of a step-up turns ratio of primary to secondary, but this gain usually does not exceed 2 or 3 to 1. Since there is no physical d-c connection between stages, plate and bias voltages are kept separate, and the a-c signal is coupled from the plate of one stage to the grid of the following stage by mutual inductive coupling between primary and secondary windings.

Transformer coupling is generally used for interstage applications with electron tubes having plate resistances of 5 to 10 thousand ohms maximum, since higher plate resistances require excessively larger transformer primary inductances. For output stages, lower plate resistances are used, and the transformer is carefully designed to handle larger plate currents. Generally speaking, a lower plate current produces fewer d-c core saturation effects.

Since the impedance transformation in a transformer varies as the square of the turns ratio between primary and secondary, output and input matching is possible and is a common practice. For interstage applications, matching is not always used, because power output is not required; in these cases, more attention is given to the step-up ratio to provide a higher voltage gain.

The limitations of frequency response generally restrict the use of transformer coupling to audio circuits which do not require an exceptionally wide bandpass or frequency response, but do require voltage or power outputs.



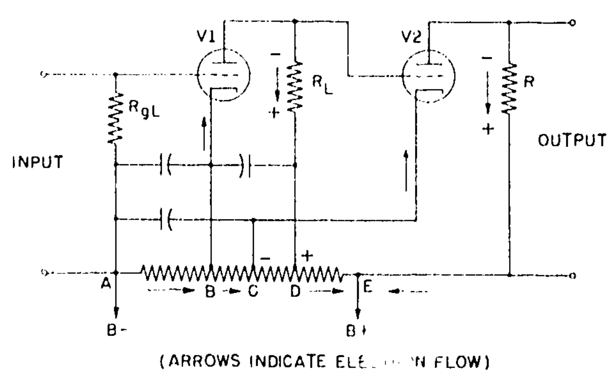
e_s – INPUT SIGNAL.
e_p – PRIMARY SIGNAL VOLTAGE.
e_i – INPUT VOLTAGE TO SECOND TUBE.

20.97
Figure 15-34.—Transformer-coupled voltage amplifier.

DIRECT COUPLING

In a direct-coupled amplifier (fig. 15-35), the plate of the driver stage is connected to the grid of the driven stage, and the coupling network is eliminated. Since the plate and bias circuits are not isolated by a transformer or coupling capacitor, the direct-coupling circuitry is slightly complicated by the arrangement necessary to produce an effective negative bias.

Because a coupling network is not inserted between the output of one tube and the input of the following tube, there is no phase distortion, time delay, or loss of frequency response. Since the plate and grid of the tubes are directly connected, the low-frequency response is extended to direct current (zero frequency). The high-frequency response is limited only by the tube interelectrode-to-ground capacitance, plus the



20.102
Figure 15-35.—Direct-coupled amplifier.

circuit distributed wiring capacitance. By appropriate matching (or mismatching) of tubes, high values of amplification and power output may be obtained.

Since the use of more than two stages requires plate voltages two or more times the normal value for one tube, plate supply considerations limit direct coupling to a few stages. Any change in the supply voltage affects the bias of all the tubes and is cumulative; therefore, special voltage supply regulation circuits are necessary. Noise and thermal effects in tubes produce circuit instability and drift that limit the use of this type of coupling in audio or RF amplifiers.

Because of its ability to amplify direct current (zero frequency), direct-coupled circuitry is often used in computer circuits, and in the output circuits of video amplifiers. It is also used in pulse circuits because response is practically instantaneous.

BASE LEAD CURRENT

The amount of transistor current depends on several variables, such as type of bias, (fixed bias, self-bias), magnitude of the input signal, basic transistor connection, type of transistor, and direction of current flow in the base lead. For example, if the base lead current is flowing into the base material in the P-N-P (fig. 15-36, view A), or out of the base material into the base lead in an N-P-N, as in view B, more current is flowing in the emitter. If the reverse is true, as shown in views C and D, then more current is flowing in the collector.

The transistor amplifiers described earlier were biased in forward and reverse directions through the use of two batteries. The purpose for using two batteries was to simplify the explanation of transistor operation. In actual practice, two batteries are seldom used. Single source biasing will point out the necessity for knowing in which direction base lead current is normally flowing.

SINGLE SOURCE BIASING

Single source biasing has the advantage of using the existing power supply to satisfy the needs for transistor biasing. This not only eliminates the need for a separate power supply, but also simplifies circuit wiring. The main reason for simplification is that both the collector and the base require voltages, which possess the same polarity with respect to the emitter, for biasing purposes.

A transistor with its three doped elements may be simplified to three resistances in series with each other. Figure 15-37, view A, shows the schematic diagram of an N-P-N transistor. Its three elements can be broken down into their equivalent electrical representation shown in view B. Now, by application of a negative source to the emitter material, that point is made the most negative in the branch, while the collector material is the least negative. In view C, point B is less negative than point A, or positive with respect to point A. In effect, the base is made positive with respect to the

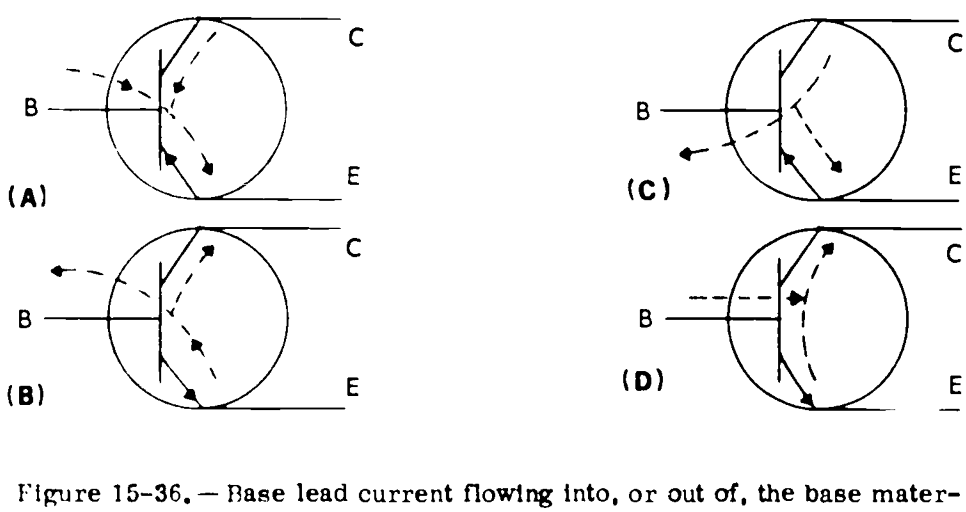


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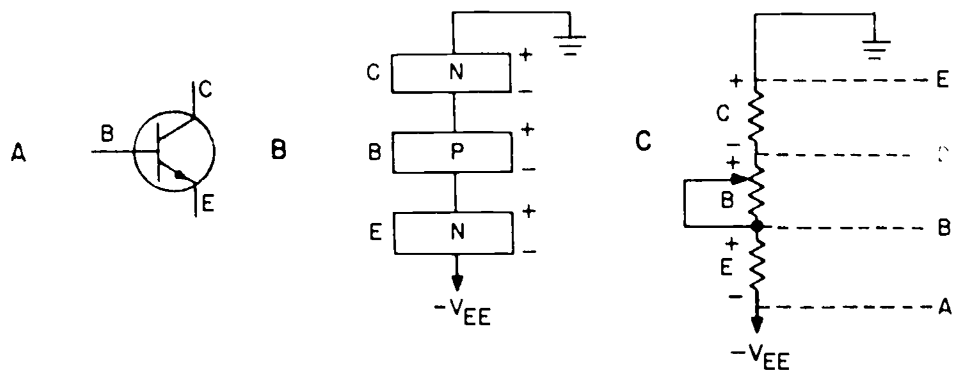
Figure 15-36. — Base lead current flowing into, or out of, the base material in N-P-N and P-N-P transistors.



179.104

Figure 15-37.—Schematic diagram of an N-P-N transistor broken down to equivalent electrical representation and resistance equivalent.

emitter, and the requirements for forward bias in an N-P-N transistor are met.

The base material, being situated between the collector and the emitter, will always find itself electrically at some potential between the collector and the emitter. Also, the base is represented in view C of figure 15-37 as a variable resistance to show that an increase in forward bias should decrease this resistance. When the arm moves from point B to point D, the total resistance in the circuit is effectively decreased, flow from point D is at the same potential as point B with respect to point A, giving more forward bias; and more current is allowed to flow from the collector to the emitter. When the arm is moved back to point B, the total resistance is increased, decreasing the current flow in the circuit; now point B is less positive than point D with respect to point A, resulting in less forward bias.

Figure 15-38 illustrates the P-N-P, again three equivalent resistances are used and this time a positive source is applied to the emitter source terminal. It may be noted that point A is the most positive point in the network and that point B is less positive than point A, while point D is less positive than (negative with respect to) point B. In this P-N-P, the bias is negative with respect to the emitter, which satisfies the forward bias requirement for this type of transistor. Once more, the base is

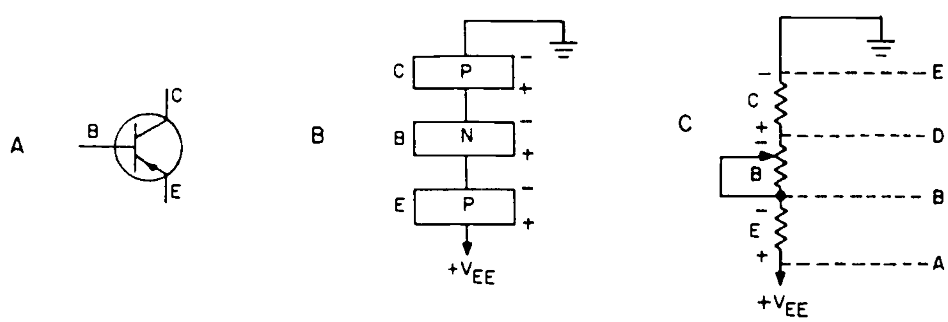


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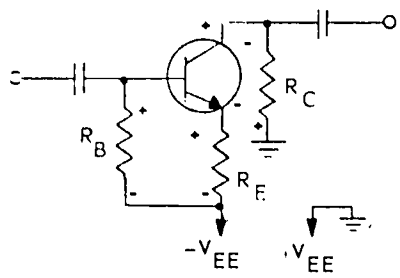
Figure 15-38.—Schematic diagram of a P-N-P transistor broken down to equivalent electrical representation and resistance equivalent.



179.106

Figure 15-39.—Establishing transistor polarities.

shown as a variable resistance to illustrate that forward bias can be increased or decreased.

The addition of a single resistor from the base to the emitter source terminal simply shunts the base-emitter junction, further decreasing its resistance, permitting more forward bias to be applied. Should the base current flow increase and, consequently, the transistor current flow, with no signal input, you should check the value of R_B; an open base resistor would allow a greater difference of potential to be felt between the base and the emitter and therefore more current through the transistor. The base-emitter resistor reduces the resistance of the base-emitter junction, reducing the amount of forward bias with no signal applied. A direct short circuit from the base to the emitter would of course cause all signal to be lost and an excessive amount of current flow through the device. By considering the transistor as being three resistances in series, you can always establish the polarity of any given material in respect to an adjacent material, regardless of the polarity of the source, as shown in figure 15-39.

The N-P-N transistor may have its collector connected to a positive source as shown in figure 15-40, view A. In this case, point E in view C is positive in respect to point D, point D is positive in respect to point C, and point C is positive with respect to point B. The base is positive with respect to the emitter, and, therefore, it is forward biased. Where a P-N-P transistor has a negative source on its collector, (fig. 15-40, view B), point E in view C is negative with respect to point D, point D is negative with respect to point C, and point C is negative with respect to point B. The base is thus negative with respect to the emitter and in a P-N-P this is forward bias. In both cases R_B is shunting the base to emitter junction.

TESTING ELECTRON TUBES

There are two types of equipment in general use for testing electron tubes: emission and transconductance testers. The emission tester indicates the ability of a tube to emit electrons from its cathode. Transconductance testers not only indicate this ability of an electron tube but also the ability of its grid voltage to control plate current. The TV-7/U tube tester is a typical transconductance-type of tester (fig. 15-41). With the front panel controls of this tester, you adjust (or switch) the various potentials necessary for testing tubes. The tube data chart that is supplied with the tester lists the control settings for the most common types of tubes.

Before inserting a tube in the correct test socket, make certain that the front panel controls are set to the positions listed in the data

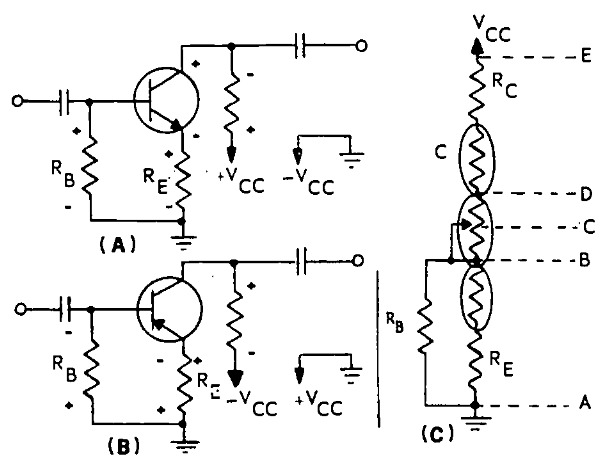


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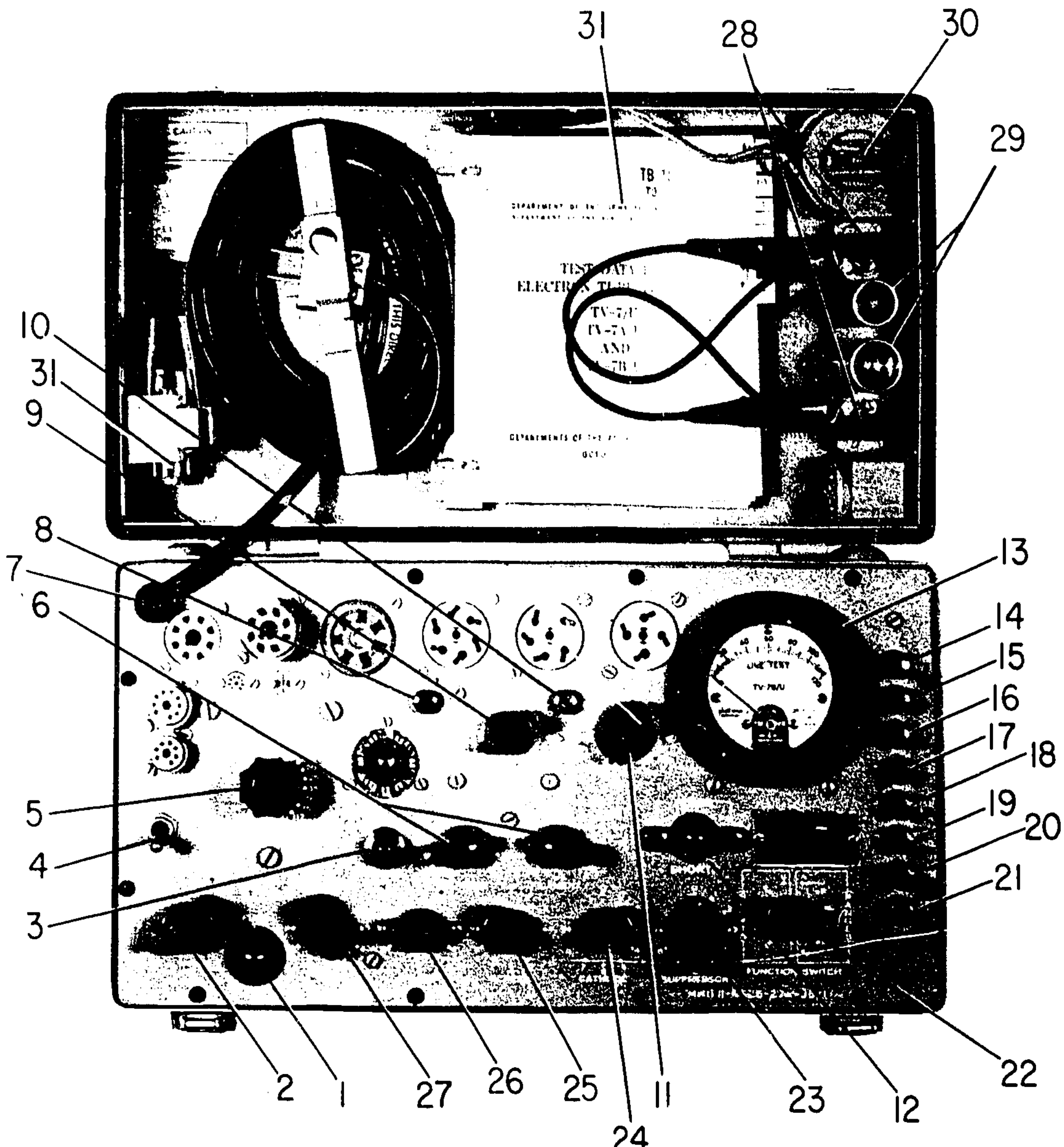
Figure 15-40.—N-P-N and P-N-P transistor equivalent circuit.



1. Fuse lamp.
2. Line adj. control.
3. Pilot light.
4. Power switch.
5. Filament voltage.
6. Filament selectors.
7. A-c line cords.
8. Grid jack.
9. Bias control.
10. Plate jack.
11. Shunt control.
12. Neon lamp.
13. Meter.
14. Meter reverse switch.
15. Rectifier switch.
16. OZ4 switch.
17. Gas 2 switch.
18. Gas 1 switch.
19. Mut. Cond. switch.
20. Diode switch.
21. Line adj. switch.
22. Function switch.
23. Suppressor selector.
24. Cathode selector.
25. Screen selector.
26. Plate selector.
27. Grid selector.
28. Test leads.
29. Pin straighteners.
30. Adapter.
31. Test data book.

243.379

Figure 15-41.— Electron Tube Test Set, TV-7/U chart for that tube. This precaution is necessary to prevent excessive voltage from being applied to the tube elements (especially the filament).

LINE VOLTAGE ADJUSTMENT AND TEST

The line voltage adjustment is necessary so that the line voltage applied to the primary of the transformer can be present to an operating value. A 93-volt potential is used as a test reference point, regardless of the variations caused by different tube loads or fluctuations in the a-c supply. Applied voltages may range from 105 to 130 volts and still be adjustable. Depressing the LINE TEST button connects the meter of the tube tester to read the "B" supply voltage. The test equipment is calibrated at the factory so that the meter pointer is approximately centered when the voltage across the primary is 93 volts. Since various types of electron tubes draw different values of currents, a LINE ADJUSTMENT rheostat (connected in series with the primary) is provided. The primary voltage can thus be set to the designed operating voltage before any test is begun. A small protective lamp which will burn out on overload is connected in series with the primary of the transformer to prevent equipment damage.

SHORT CIRCUIT AND NOISE TEST

It is very important that the technician apply the test for short-circuited elements to a tube of doubtful quality before any other tests are made. This procedure protects the meter (or any other indicator) from damage. Also it follows logically that, if a tube under test has elements which are short-circuited, there is no further need to apply additional tests to that tube. Short-circuit tests are usually sensitive enough to indicate leakage resistance less than about one-fourth megohm. The proper heater voltage is applied so that any tube elements which might short as a result of the heating process will be detected. The short-circuit test is similar to the test used to detect noisy (microphonic) tubes caused by loose elements. Since the only difference between the two tests is in the sensitivity of the device used as an indicator, the noise test is discussed as part of the short-circuit test.

Figure 15-42 shows a basic circuit used for detecting shorted elements within a tube. With the switch set to position 2 as shown, the plate of the tube under test is connected to the leg of the transformer secondary containing the neon lamp. All the other elements are connected through switches to the other leg of the secondary. If the plate element of the tube is touching any other element within the tube, the a-c circuit of the secondary is completed and as a result, both plates of the neon lamp glow. If no short exists, only one plate of the neon lamp will glow. Each of the other elements is tested by means of the switching arrangement shown. Resistor R2 limits the current through the neon lamp to a safe value. Resistor R1 bypasses any small alternating currents in the circuit which might be caused by stray capacitance and thus prevents the neon lamp from indicating erroneously. Tapping the tube lightly is recommended to detect loose elements which might touch when the tube is vibrated.

The circuit used to test for shorts is similar to the basic circuit of figure 15-42. By means of

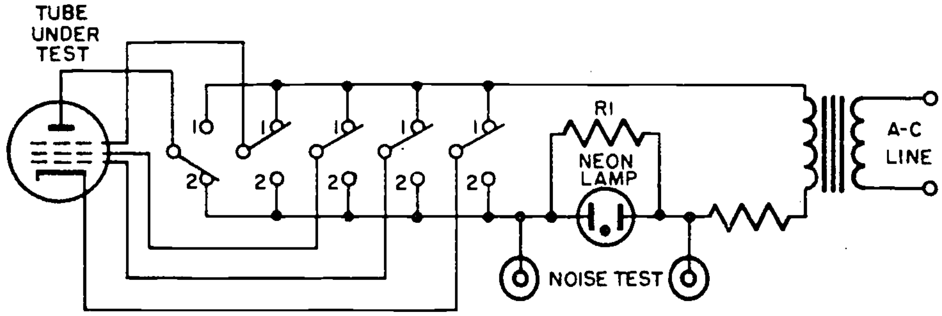


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Figure 15-42.—Basic circuit used for short circuit and noise test.

the function switch the electrodes of the tube under test are switched in turn across a neon SHORTS lamp, which is connected in series with the secondary of the transformer. Shorted tube elements (and any other internal tube connections) complete the a-c circuit, causing both plates of the neon lamp to glow. Momentary flashes of the neon SHORTS lamp may be caused when the switch is rotated. These flashes are caused by the charging of the small interelectrode capacitances of the tube when the voltage is applied, and do not indicate short circuits. If the tube under test has a shorted element, the neon lamp will glow continually on one or more switch positions. Since the filament circuit and other internal tube connections will show up as short circuits in this test, the tube data chart should be consulted for pin connection information before interpreting the results of the test.

The noise test is used to check for intermittent shorts or microphonic noise. The circuit used is the same as that employed for the short-circuit test. In tests for noise, the antenna and ground terminals of a radio receiver are connected to the NOISE TEST receptacles. Any intermittent short between tube electrodes permits the a-c voltage from the power transformer to be applied momentarily to the neon lamp.

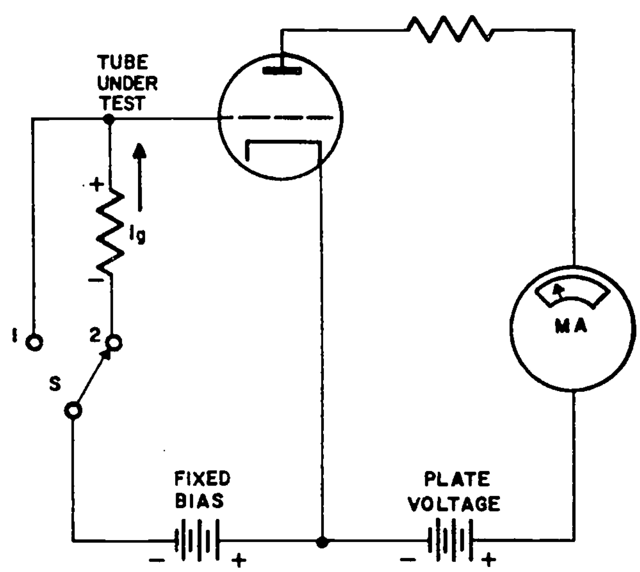
The brief oscillation of this lamp contains various radiofrequencies which are reproduced as audible signals in the receiver speaker. A less sensitive noise test can be made using a pair of headphones instead of the radio receiver. The tube should be tapped while it is being tested.

GAS TEST

In all electron tubes, except some types of rectifier tubes and thyratrons, the presence of any appreciable amount of gas is extremely undesirable. When gas is present, the electrons emitted by the cathode collide with the molecules of gas. As a result of these collisions, electrons (secondarily emitted) are dislodged from the gas molecules, and positive gas ions are formed. These ions are attracted by (and cluster around) the control grid of the tube, absorbing electrons from the grid circuit in order to revert to the more stable gas molecules (not ionized). If the amount of gas in the tube is appreciable, the collisions between the numerous gas molecules and the cathode-emitted electrons release many secondarily emitted electrons, and the resulting flow of grid current is high.

The basic circuit used for the gas test is shown in figure 15-43. With switch S set to position 1, a certain value of plate current is measured by the d-c milliammeter. If there is no gas (or a negligible amount) present in the tube, setting switch S to position 2 does not change the plate-current reading. If gas is present, current flows through the grid resistor (large value), causing a voltage drop to develop with the polarity as shown. The net effect is to reduce the negative bias voltage on the grid the tube resulting in an increase of plate current. Small plate current increases are normal; large increases indicate excessive gas.

The value of the grid resistor used in the typical tube tester is 180,000 ohms. Two push-button switches, labeled GAS No. 1 and GAS No. 2, are used for gas test. GAS No. 1 button is first depressed and the plate current reading on the meter is noted. Depressing the button marked GAS No. 2 inserts the 180,000-ohm resistor into the grid circuit. If gas is present in the tube, the grid current that flows reduces the normal bias on the tube and increases the plate current measured by the meter. A tube with a negligible amount of gas produces an increase in plate current of less than one scale division when GAS No. 2 button is depressed. An increase of more than one scale division indicates an excessive amount of gas in the tube.



1.76
Figure 15-43.—Basic circuit used for gas test.

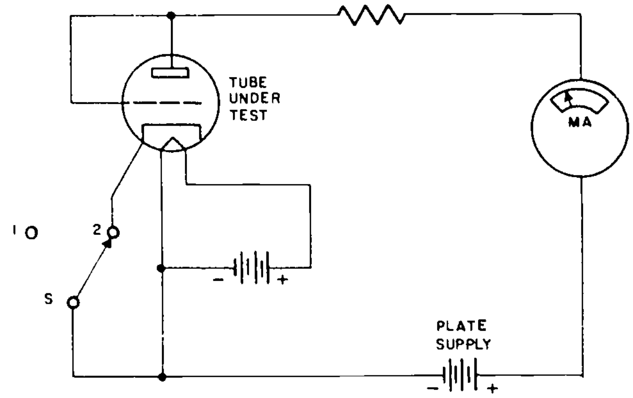
CATHODE LEAKAGE TEST

When a tube which uses an indirectly heated cathode develops noise, it is almost a certain indication that a leakage path is present between the cathode sleeve and the heater wire. This assumption is justified because in the design of a tube the heater must be placed as close as possible to the cathode so that maximum tube efficiency is attained. Continual heating and cooling of the tube structure may cause small amounts of the insulation between the cathode and heater to become brittle or deteriorate, leaving a high resistance leakage path between these elements. Under extreme conditions the insulation may shift enough to allow actual contact of the elements. Since the heater and cathode are seldom at the same potential, any form of leakage causes noise to develop in the tube.

The cathode normally is maintained at a higher positive potential, because cathode bias is the most common type of bias utilized. The heater circuit is usually grounded to chassis, either on one side of the filament supply or by a center-tap arrangement. Therefore, if a resistance path is present, a leakage current may flow from the heater to the cathode. Thus, in effect, the cathode functions in the same manner as the plate of a tube; that is, it receives electrons. Assuming the existence of a high-resistance short, the current flow from the heater to the cathode will vary with any vibration of the tube because vibration varies the amount of resistance. If the cathode and heater are completely shorted (zero ohms), it is impossible for the tube to develop any cathode bias.

A cathode leakage test is sometimes made while a tube is being tested for short-circuited elements or noise. However, some tube-testing instruments incorporate the cathode leakage test as an additional test which is not part of the short-circuit test. Figure 15-44 shows a basic circuit which is used to detect leakage between the heater and cathode elements of a tube. With switch S set to position 2, a certain value of plate current flows.

When switch S is set to position 1, the cathode becomes a floating element; if no leakage path is present, the plate current should fall to zero. If the elements are completely shorted, the plate current reading remains the same as the initial reading (switch S in position 2); if they are only partially shorted, a plate current less than normal but greater than zero is indicated.



1.77
Figure 15-44.—Basic circuit used for cathode leakage test.

FILAMENT ACTIVITY TEST

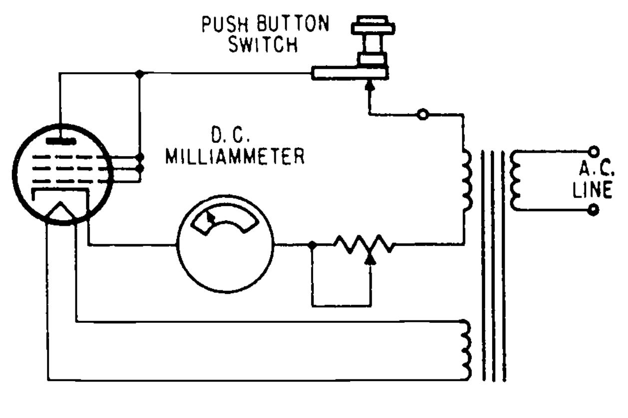
The filament activity test is used to determine the approximate remaining life of an electron tube insofar as the longevity of the cathode emitter is concerned. The test is based on the principle that the cathode in almost all electron tubes is so constructed that a decrease of 10 percent of the rated heater voltage causes no appreciable decrease in emission.

On tube-testing equipment incorporating this test, there is a two-position switch (FILAMENT ACTIVITY TEST) which has one position marked NORMAL and the other marked TEST. The switch remains in the NORMAL position for all tests other than the filament activity test. When the switch is set to the TEST position, the filament (or heater) voltage which is applied to the tube under test is reduced by 10 percent.

The filament activity test is performed as follows: After the quality test is made, the TUBE TEST button is held depressed, and the filament activity test switch is set to TEST position. If the indicator shows a decreased reading after a reasonable time is allowed for the cathode to cool, the useful life of the tube is nearing its end.

RECTIFIER TEST

The circuit used for testing full-wave rectifiers, diodes, and OZ4 (cold-cathode rectifier) tubes is an emission test circuit which is similar to the basic circuit shown in figure 15-45. An a-c voltage of definite value is applied to the



1.73
Figure 15-45.— Basic circuit used for emission test.

tube under test, and the meter indicates the rectified plate current. The two sections of a full-wave rectifier are tested separately.

The button for testing OZ4 tubes provides a higher a-c voltage than is normally used for heater (or filament) type rectifiers. The button for diode tubes provides a lower voltage than that used for regular rectifiers, and also inserts a protective series resistance.

QUALITY TEST

For the quality test, the d-c grid bias for the tube under test is supplied by a rectifier tube. The correct value of this grid bias is obtained when the bias control is rotated to the setting listed in the test data chart, for the tube being tested. An a-c voltage (4.7 volts rms), which is taken from a separate winding on the power transformer, is applied in series with the grid bias. This voltage causes the grid to deviate in positive and negative directions from the d-c bias level, thereby effecting the grid-voltage change required for a dynamic transconductance test. The plate voltage of the tube under test is supplied by a rectifier tube. The meter which indicates the plate current change is in the return circuit of the rectifier supply. The meter indicates the tube condition in arbitrary numerical units from 0 to 120. The tube test data book, mounted inside the cover of the equipment, lists the minimum numerical value of meter reading for satisfactory performance. Tubes reading below this value are not considered su[illegible] military equipment. The shun[illegible]d to control the sensitivity of the meter. Setting of the dial is required only when the function switch is in the RANGE (A) SHUNT position. The setting for this switch is determined by the type of tube being tested and is listed in the tube data chart.

TESTING TRANSISTORS

Transistors should be checked with the Transistor Test Set TS-1100/U (fig. 15-46). If a test set is not available, it is possible to test transistors with a multimeter or a vacuum tube voltmeter (VTVM).

The TS-1100/U is designed to measure the current gain (beta) and collector leakage current (I_{CO}) of a transistor. It will also detect short circuits.

Beta is defined as the ratio of change in collector current to a change in base current, collector voltage being constant. I_{CO} is a measure of leakage current between the base and collector, when the base-collector junction is reverse-biased and the emitter-base junction is open-circuited.

With a transistor tester, beta may be measured with the transistor in or out of its circuit. You must remove the transistor from its circuit to test for shorts and to measure I_{CO}.

SEMICONDUCTOR TESTING

When using a multimeter to test semiconductors, to avoid loading the circuit, the multimeter must have a sensitivity of at least 20,000 ohms per volt on all voltage ranges; the ohmmeter circuits must not pass a current exceeding 1 milliampere. The VTVM should have an input resistance of 11 megohms or more, and must have an isolation transformer between the meter and the powerline.

Three tests can be accomplished on the transistor by using the multimeter. However, the transistor must be removed from the circuit for testing.

Determine the type of transistor, whether P-N-P or N-P-N. The same resistance test can be performed on the transistor as on the diode. The transistor has two junctions, the emitter-base and the collector-base. Because each junction can be treated as a diode, the same readings hold true.

Before a diode is tested, its polarity must be determined. The diode is usually marked with a plus (+) or minus (-) sign. Connect the test

72.37

Figure 15-46.—Transistor Test Set, TS-1100/U.

leads to the diode in a forward bias condition, that is, the positive lead to the positive side of the diode and the negative lead to the negative side. Current will now flow easily, and if a reading of 1000 ohms or less is obtained, this part of the test is good. If a higher reading is obtained, the diode is open.

Connect the test leads to the diode in a reverse bias condition—the positive lead to the negative side of the diode and the negative lead to the positive side. Current will not flow readily, and a reading in excess of 10,000 ohms should be obtained. If a reading under 10,000 ohms is obtained, the diode is shorted.

As a general rule, the front-to-back ratio should be at least 10 to 1. When testing power transistors, the same ratio (10 to 1) holds true, except that the reverse resistance must be in excess of only 1000 ohms.

Since damage to transistors could occur when using voltages above approximately 6 volts, care must be taken to avoid using resistance scales where the internal voltage of the ohmmeter is greater than 6 volts. This higher potential is usually found on the higher resistance scales. Excess current might also cause damage to the transistor under test. Since the internal current-limiting resistance generally increases as the resistance range is increased, the low range of the resistance scale should also be avoided. Basically, if we stay away from the highest resistance range (possible excessive voltage) and the lowest resistance range (possible excessive current), the ohmmeter should present no problems in transistor testing. Generally speaking, the R x 10 and R x 100 scales may be considered safe.

The polarity of the battery, as well as the voltage value, must be known when using the ohmmeter for transistor testing. Although, in most cases, the ground or common lead (black) is negative and the hot lead (red) is positive, this battery setup is not always the case.

It is possible to reverse the polarity of the ohmmeter leads by changing the function switch position. This means that the black or common lead is now the positive battery and the red lead is the negative battery.

CAUTION:

- Although the jacks of the meter may show a negative sign under the common and a positive sign under the other jack, these do not indicate the internal polarity of the battery connected to the jack.

- Before making any resistance measurements, make sure that all power to the circuit under test has been disconnected and that all capacitors have been discharged.

- Do not use an ohmmeter which passes more than one milliampere through the circuit under test.

- Ensure that all test equipment is isolated from the powerline either by the equipment's own power supply transformer or by an external isolation transformer.

- Always connect a ground lead between COMMON for the circuit under test and COMMON on the test equipment.

- Do not short circuit any portion of a transistor circuit. Short circuiting individual components or groups of components may allow excessive current to flow, thus damaging components.

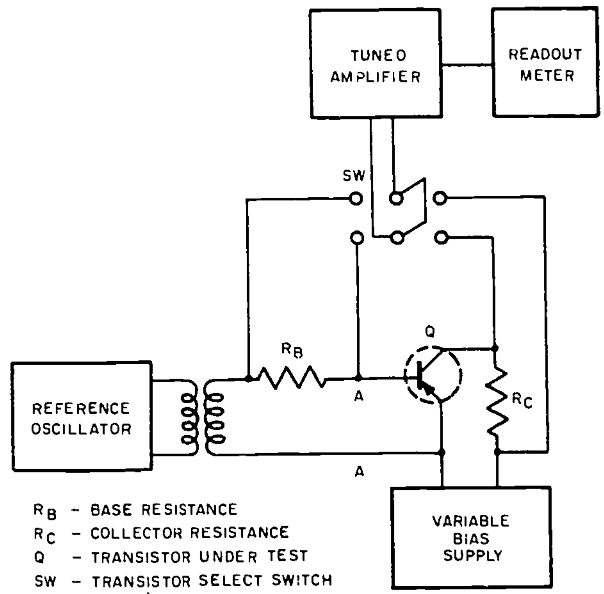
- Do not remove or replace any transistors in an energized circuit.

I_{CO} TEST

High collector leakage current (I_{CO}) is caused by old age and excessive temperatures. I_{CO} is greatly dependent on ambient temperature, thus care must be taken to see that temperature is controlled when measuring I_{CO}.

One sign of a defective transistor is instability of I_{CO}. Whenever I_{CO} increases slowly while being measured, it is quite evident that the transistor is defective. Excessive leakage current indicates transistor deterioration and usually is accompanied by lower than normal beta. Common causes of excessive I_{CO} include age, high ambient temperature, and contaminates that form on the emitter-base junction or collector-base junction.

Figure 15-47 shows the test circuit for measuring I_{CO}. The transistor must be out of the circuit for this test. If I_{CO} were measured with the transistor in the circuit, the indicated I_{CO} would be higher than the actual I_{CO} due to shunt current paths in the circuit.



124.223

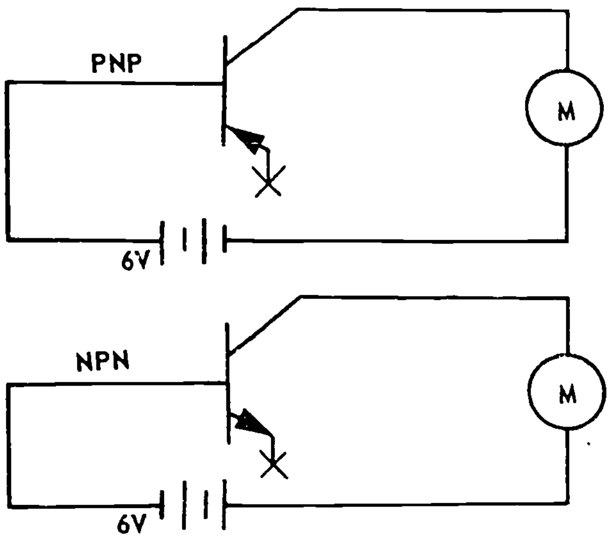
Figure 15-47.— Measuring beta, using Transistor Test Set, TS-1100/U.

To perform the leakage current test, the manufacturer's specifications should be consulted to ascertain the allowable limits. Determine the type of transistor and set up one of the tests shown in figure 15-48, using a 6-volt battery and microammeter.

If the leakage current is twice as much as the specification sheet calls for, replace the transistor. If no specifications are available, use the following rule of thumb:

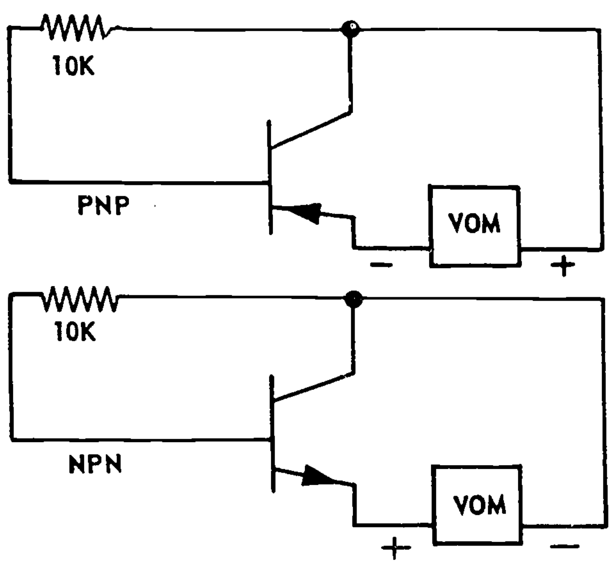
1. Silicon transistor — less than 1 microamp.
2. Small germanium transistor — less than 10 microamps.
3. Medium germanium transistor — less than 100 microamps.
4. Power transistors — less than 1 milliampere.

The beta test can be accomplished by inserting a 10,000-ohm resistor between the collector-base junction and connecting the meter to the emitter and collector as shown in figure 15-49.



71.99

Figure 15-48.—Transistor leakage current test.



71.100

Figure 15-49.—Transistor gain test.

Once the resistance is obtained on the meter, use the following formula to figure the gain: B = 1200 ÷ R. The letter B represents gain, 1200 is a constant, and R is the resistance read on the meter.

Check the manufacturer's specifications for the gain of each transistor. If the specifications are not available, use the following rule of thumb:

1. Silicon transistors—5 times or more.
2. High-frequency transistors—10 times or more.
3. All other transistors—15 times or more.

Whenever a particular transistor is suspected to be faulty, it may be tested in the circuit if there are no low resistance shunts (such as coils, forward biased diodes, low value resistors, and so forth) across any of its leads. A low resistance shunt across any two of the transistor leads can easily cause erroneous indications on the transistor test set.

Erroneous indications can be eliminated by removing the suspected transistor from the circuit. Some manufacturers have simplified the removal and replacement of transistors by using transistor sockets. Whenever a circuit board without transistor sockets is encountered, transistors will have to be carefully unsoldered in order to test them out of circuits.

MEASUREMENTS IN TRANSISTOR CIRCUITS

The many types of transistor base connection arrangements require that the leads be properly identified to secure correct hookup to the tester. The TS-1100/U test socket arrangement is compatible with some transistor types, but not all types. If the leads are long enough, it is generally possible to effect proper hookup by bending them. If the leads are too short, it will be necessary to use the test cable and alligator clips provided with the tester. In all cases, however, the transistor leads should be identified and then matched up with the tester connections.

The advantage of the TS-1100/U lies not only in its accuracy and simplicity, but also in its use of a-c as the testing current. This eliminates interference from direct currents and voltages that may be present and permits measurement of the gain of a transistor in-circuit, thus making it unnecessary to unsolder or disconnect the the transistor for this test. This is particularly advantageous where the transistor is mounted on a module printed wiring board.

The test set has the following additional features: a switch marked P-N-P-N-P-N, which selects the proper bias polarity for the type of transistor under test; a temperature alarm indicator lamp, which will light when the ambient temperature surrounding the equipment exceeds 50° C; and a switch marked TEST, which checks the test set battery output.

The test set is also equipped to indicate a short between any two of the three elements of the transistor under test. With the transistor in-circuit, it will also indicate a short if the circuitry between any two of the transistor elements has a resistance of 500 ohms or less. To determine whether the short is in the transistor itself or in the associated circuit, it is necessary to remove the transistor from the circuit.

A table in the instruction manual for the test set gives a numerical listing of the transistors that can be tested. The technical manual for the test set provides information concerning the collector bias to be applied for a particular transistor and the maximum permissible collector leakage current. When the instrument is adjusted according to the instruction book, the value of beta will be indicated directly on the meter.

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APPENDIX I

THE METRIC SYSTEM

The metric system was developed by French scientists in 1790 and was specifically designed to be an easily used system of weights and measures to benefit science, industry, and commerce. The metric system is calculated entirely in powers of 10, so one need not work with the various mathematical bases used with the English system, such as 12 inches to a foot, 3 feet to a yard, and 5280 feet to a mile.

The system is based on the "meter" which is one ten-millionth of the distance from the Equator to the North Pole. It is possible to develop worldwide standards from this base of measurement. The metric system of weights is based on the gram, which is the weight of a specific quantity of water.

Soon after the system was developed scientists over the world adopted it and were able to deal with the mathematics of their experiments more easily. The data and particulars of their work could be understood by other scientists anywhere in the world. During the early 19th century many European nations adopted the new system for engineering and commerce. It was possible for these countries to trade manufactured goods with one another without worrying whether it would be possible to repair machinery from another country without also buying special wrenches and measuring tools. Countries could buy and sell machine tools and other sophisticated and precision machinery without troublesome modifications or alterations. It was much easier to teach the metric system, since meters can be changed to kilometers or centimeters with the movement of a decimal point, which is roughly like being able to convert yards to miles or inches by adding zeros and a decimal instead of multiplying by 1760 or dividing by 36.

With the exception of the United States, all the industrialized nations of the world have adopted the metric system. Even England and Canada are changing from their traditional systems of measure, and the metric system will be almost universal by 1980.

Although the metric system has not been officially legislated by the Congress, the metric system is becoming more prominent in this country. Most automobile mechanics own some metric wrenches to work on foreign cars or foreign components in American cars. Almost all photographic equipment is built to metric standards. Chemicals and drugs are usually sold in metric quantities, and "calorie counters" are using a metric unit of thermal energy.

Because we are allied with countries who use the metric system, much of our military information is in metric terms. Military maps use meters and kilometers instead of miles, and many weapons are in metric sizes, such as 7.62 mm, 20 mm, 40 mm, 75 mm, and 155 mm. Interchange of military equipment has caused a mixture of metric and English measure equipment since World War I when the army adopted the French 75 mm field gun, and World War II when the Navy procured the Swedish 40 mm Bofors and the Swiss 20 mm Oerlikon heavy machine guns.

It is inevitable that the United States will officially adopt the metric system. Exactly when this happens and how rapidly the changeover will depend on economics, since the expense of retooling our industry and commerce to new measurements will be very great. The cost of conversion will be offset by increased earnings from selling machinery and products overseas. Another benefit is that scientists use the metric system, but their calculations now have to be translated into English measure to be used by industry. With adoption of the metric system ideas can go directly from the drawing board to the assembly line.

The Navy will be using the metric system more during the next few years. Although you will find it easier to solve problems using this system, at first you will find it difficult to visualize or to estimate quantities in unfamiliar units of measure.

Fortunately, many metric units can be related to equivalent units in the English system.

The meter which is the basic unit is approximately one-tenth longer than a yard.

The basic unit of volume, the liter, is approximately one quart. The gram is the weight of a cubic centimeter, or milliliter, of pure water and is the basic unit of weight. As a common weight though, the kilogram, or kilo, which equals the weight of a liter of water, weighs 2.2 pounds. The cubic centimeter (cc) is used where we would use the square inch, and where we measure by the fluid ounce, the metric system employs the milliliter (ml). For power measure the metric system uses the kilowatt (kW), which is approximately 1.3 horsepower.

In terms of distance, a land mile is eight-fifths of a kilometer and a nautical mile is 1.852 kilometers, or nearly 2 kilometers.

A basic metric expression of pressure is the kilogram per square centimeter, which is 14.2 psi, nearly 1 atmosphere of pressure.

When working on foreign machinery, you may notice that your half-inch, three-quarter inch, and one-inch wrenches will fit many of the bolts. These sizes correspond to 13 mm, 19 mm, and 26 mm respectively in the metric system, and are very popular because they are interchangeable. The 13/16-inch spark plug wrench, which is standard in this country, is intended to fit a 20 mm nut.

The basic quantities of the metric system are multiplied or divided by powers of 10 to give other workable values. We cannot easily measure machine parts in terms of a meter, so the millimeter, or one-thousandth of a meter is used. For very fine measure the micron, also called the micrometer, can be used. It is one-millionth part of a meter, or one-thousandth of a millimeter. For small weights the milligram, one-thousandth of a gram is used. All of these multiples are expressed with standard prefixes taken from Latin:

micro	= 1/1,000,000
milli	= 1/1,000
centi	= 1/100
*deci	= 1/10
*deca	= 10
*hecto	= 100
kilo	= 1,000
*myria	= 10,000
mega	= 1,000,000

* Rarely used

Over the next few years the metric system will become more used by the Navy as well as by the civilian world. You will find it easy to work with once you have mastered the basic terms. It will be difficult to translate values from our present system to the metric system, but this operation will become unnecessary once the new measurements are totally adopted.

Tables of equivalent English measure and metric equivalents are essential when you work simultaneously with both systems. The table which follows shows the equivalent measures of the two systems. The columns on the left have the equivalent values which are accurate enough for most work, and on the right are the multiples used to convert the values with a high degree of accuracy.

U.S. CUSTOMARY AND METRIC SYSTEM UNITS OF MEASUREMENTS

THESE PREFIXES MAY BE APPLIED TO ALL SI UNITS

Multiples and Submultiples	Prefixes	Symbols
1 000 000 000 000 = 10^{12}	tera (tĕr'ȧ)	T
1 000 000 000 = 10^{9}	giga (jĭ'gȧ)	G
1 000 000 = 10^{6}	mega (mĕg'ȧ)	M •
1 000 = 10^{3}	kilo (kĭl'ô)	k •
100 = 10^{2}	hecto (hĕk'tô)	h
10 = 10	deka (dĕk'ȧ)	da
0.1 = 10^{-1}	deci (dĕs'ĭ)	d
0.01 = 10^{-2}	centi (sĕn'tĭ)	c •
0.001 = 10^{-3}	milli (mĭl'ĭ)	m •
0.000 001 = 10^{-6}	micro (mī'krô)	μ •
0.000 000 001 = 10^{-9}	nano (năn'ô)	n
0.000 000 000 001 = 10^{-12}	pico (pē'kô)	p
0.000 000 000 000 001 = 10^{-15}	femto (fĕm'tô)	f
0.000 000 000 000 000 001 = 10^{-18}	atto (ăt'tô)	a

• MOST COMMONLY USED

ENGLISH AND METRIC SYSTEM UNITS OF MEASUREMENT

COMMON EQUIVALENTS AND CONVERSIONS

Approximate Common Equivalents		Conversions Accurate to Parts Per Million (units stated in abbreviated form) Number X Factor	
1 inch	= 25 millimeters	in X 25.4*	= mm
1 foot	= 0.3 meter	ft X 0.3048*	= m
1 yard	= 0.9 meter	yd X 0.9144*	= m
1 mile†	= 1.6 kilometers	mi X 1.60934	= km
1 square inch	= 6.5 square centimeters	in^2 X 6.4516*	= cm^2
1 square foot	= 0.09 square meter	ft^2 X 0.0929030	= m^2
1 square yard	= 0.8 square meter	yd^2 X 0.836127	= m^2
1 acre	= 0.4 hectare	acres X 0.404686	= ha
1 cubic inch	= 16 cubic centimeters	in^3 X 16.3871	= cm^3
1 cubic foot	= 0.03 cubic meter	ft^3 X 0.0283168	= m^3
1 cubic yard	= 0.8 cubic meter	yd^3 X 0.764555	= m^3
1 quart (lq.)	= 1 liter	qt (lq.) X 0.946353	= *l*
1 gallon	= 0.004 cubic meter	gal X 0.00378541	= m^3
1 ounce (avdp)	= 28 grams	oz (avdp) X 28.3495	= g
1 pound (avdp)	= 0.45 kilogram	lb (avdp) X 0.453592	= kg
1 horsepower	= 0.75 kilowatt	hp X 0.745700	= kW
1 pound per square inch	= 0.07 kilogram per square centimeter	psi X 0.0703224	= kg/cm^2
1 millimeter	= 0.04 inch	mm X 0.0393701	= in
1 meter	= 3.3 feet	m X 3.28084	= ft
1 meter	= 1.1 yards	m X 1.09361	= yd
1 kilometer	= 0.6 mile	km X 0.621371	= mi
1 square centimeter	= 0.16 square inch	cm^2 X 0.155000	= in^2
1 square meter	= 11 square feet	m^2 X 10.7639	= ft^2
1 square meter	= 1.2 square yards	m^2 X 1.19599	= yd^2
1 hectare	= 2.5 acres	ha X 2.47105	= acres
1 cubic centimeter	= 0.06 cubic inch	cm^3 X 0.0610237	= in^3
1 cubic meter	= 35 cubic feet	m^3 X 35.3147	= ft^3
1 cubic meter	= 1.3 cubic yards	m^3 X 1.30795	= yd^3
1 liter	= 1 quart (lq.)	*l* X 1.05669	= qt (lq.)
1 cubic meter	= 250 gallons	m^3 X 264.172	= gal
1 gram	= 0.035 ounces (avdp)	g X 0.0352740	= oz (avdp)
1 kilogram	= 2.2 pounds (avdp)	kg X 2.20462	= lb (avdp)
1 kilowatt	= 1.3 horsepower	kW X 1.34102	= hp
1 kilogram per square centimeter	= 14.2 pounds per square inch	kg/cm^2 X 14.223226	= psi

†nautical mile = 1.852 kilometers

* exact

INDEX

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CONSTRUCTION ELECTRICIAN 3 & 2

NAVEDTRA 10636-H

Prepared by the Naval Education and Training Program Development Center, Pensacola, Florida

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Your NRCC contains a set of assignments and self-scoring answer sheets (packaged separately). The Rate Training Manual, Construction Electrician 3 & 2, NAVEDTRA 10636-H, is your textbook for the NRCC. If an errata sheet comes with the NRCC, make all indicated changes or corrections. Do not change or correct the textbook or assignments in any other way.

HOW TO COMPLETE THIS COURSE SUCCESSFULLY

Study the textbook pages given at the beginning of each assignment before trying to answer the items. Pay attention to tables and illustrations as they contain a lot of information. Making your own drawings can help you understand the subject matter. Also, read the learning objectives that precede the sets of items. The learning objectives and items are based on the subject matter or study material in the textbook. The objectives tell you what you should be able to do by studying assigned textual material and answering the items.

At this point you should be ready to answer the items in the assignment. Read each item carefully. Select the BEST ANSWER for each item, consulting your textbook when necessary. Be sure to select the BEST ANSWER from the subject matter in the textbook. You may discuss difficult points in the course with others. However, the answer you select must be your own. Use only the self-scoring answer sheet designated for your assignment. Follow the scoring directions given on the answer sheet itself and elsewhere in this course.

Your NRCC will be administered by your command or, in the case of small commands, by the Naval Education and Training Program Development Center. No matter who administers your course you can complete it successfully by earning grades that average 3.2 or higher. If you are on active duty, the average of your grades in all assignments must be at least 3.2. If you are NOT on active duty, the average of your grades in all assignments of each creditable unit must be at least 3.2. The unit breakdown of the course, if any, is shown later under Naval Reserve Retirement Credit.

WHEN YOUR COURSE IS ADMINISTERED BY LOCAL COMMAND

As soon as you have finished an assignment, submit the completed self-scoring answer sheet to the officer designated to administer it. He will check the accuracy of your score and discuss with you the items that you do not understand. You may wish to record your score on the assignment itself since the self-scoring answer sheet is not returned.

If you are completing this NRCC to become eligible to take the fleetwide advancement examination, follow a schedule that will enable you to complete all assignments in time. Your schedule should call for the completion of at least one assignment per month.

Although you complete the course successfully, the Naval Education and Training Program Development Center will not issue you a letter of satisfactory completion. Your command will make a note in your service record, giving you credit for your work.

WHEN YOUR COURSE IS ADMINISTERED BY THE NAVAL EDUCATION AND TRAINING PROGRAM DEVELOPMENT CENTER

After finishing an assignment, go on to the next. Retain each completed self-scoring answer sheet until you finish all the assignments in a unit (or in the course if it is not divided into units). Using the envelopes provided, mail your self-scored answer sheets to the Naval Education and Training Program Development Center where the scores will be verified and recorded. Make sure all blanks at the top of each answer sheet are filled in. Unless you furnish all the information required, it will be impossible to give you credit for your work. You may wish to record your scores on the assignments since the self-scoring answer sheets are not returned.

The Naval Education and Training Program Development Center will issue a letter of satisfactory completion to certify successful completion of the course (or a creditable unit of the course). To receive a course-completion letter, follow the directions given on the course-completion form in the back of this NRCC.

You may keep the textbook and assignments for this course. Return them only in the event you disenroll from the course or otherwise fail to complete the course. Directions for returning the textbook and assignments are given on the book-return form in the back of this NRCC.

PREPARING FOR YOUR ADVANCEMENT EXAMINATION

Your examination for advancement is based on the Manual of Navy Enlisted Manpower and Personnel Classification and Occupational Standards (NAVPERS 18068-D). The sources of questions in this examination are given in the Bibliography for Advancement Study (NAVEDTRA 10052). Since your NRCC and textbook are among the sources listed in this bibliography, be sure to study both in preparing to take your advancement examination. The standards for your rating may have changed since your course and textbook were printed, so refer to the latest editions of NAVPERS 18068-D and NAVEDTRA 10052.

NAVAL RESERVE RETIREMENT CREDIT

The course is evaluated at 18 Naval Reserve retirement points, which will be credited in units as follows: Unit 1, 12 points upon completion of assignments 1 through 8; Unit 2, 6 points upon completion of assignments 9 through 12. These points are creditable to personnel eligible to receive them under current directives governing the retirement of Naval Reserve personnel. Credit cannot be given again for the course if the student has previously received credit for completing another Construction Electrician 3 & 2 NRCC or ECC.

COURSE OBJECTIVE

In completing this nonresident career course, you will demonstrate a knowledge of the subject matter by correctly answering items on the following: enlisted rating structure; principles of the advancement system; preparing for advancement; safe practices and first aid measures; safety training; reporting accidental injuries or deaths; reading and caring for blueprints, diagrams, and schematics; maintaining and operating test, protective, and control equipment; repairing, testing, and maintaining motors, generators, and electric appliances; fundamentals of interior wiring; installing and operating a central power station; installing, maintaining, and repairing overhead and underground electrical distribution systems; cable splicing; installing, servicing, and operating a telephone communications system; and fundamentals of electronic components and circuits.

While working on this nonresident career course, you may refer freely to the text. You may seek advice and instruction from others on problems arising in the course, but the solutions submitted must be the result of your own work and decisions. You are prohibited from referring to or copying the solutions of others, or giving completed solutions to anyone else taking the same course.

Naval nonresident career courses may include a variety of items -- multiple-choice, true-false, matching, etc. The items are not grouped by type; regardless of type, they are presented in the same general sequence as the textbook material upon which they are based. This presentation is designed to preserve continuity of thought, permitting step-by-step development of ideas. Some courses use many types of items, others only a few. The student can readily identify the type of each item (and the action required of him) through inspection of the samples given below.

MULTIPLE-CHOICE ITEMS

Each item contains several alternatives, one of which provides the best answer to the item. Select the best alternative and erase the appropriate box on the answer sheet.

SAMPLE

s-1. The first person to be appointed Secretary of Defense under the National Security Act of 1947 was

1. George Marshall
2. James Forrestal
3. Chester Nimitz
4. William Halsey

The erasure of a correct answer is indicated in this way on the answer sheet:

	1 T	2 F	3	4
s-1		C		

TRUE-FALSE ITEMS

Determine if the statement is true or false. If any part of the statement is false the statement is to be considered false. Erase the appropriate box on the answer sheet as indicated below.

SAMPLE

s-2. Any naval officer is authorized to correspond officially with a bureau of the Navy Department without his commanding officer's endorsement.

The erasure of a correct answer is also indicated in this way on the answer sheet:

	1 T	2 F	3	4
s-2		CC		

MATCHING ITEMS

Each set of items consists of two columns, each listing words, phrases or sentences. The task is to select the item in column B which is the best match for the item in column A that is being considered. Specific instructions are given with each set of items. Select the numbers identifying the answers and erase the appropriate boxes on the answer sheet.

SAMPLE

In items s-3 through s-6, match the name of the shipboard officer in column A by selecting from column B the name of the department in which the officer functions.

A. Officers	B. Departments
s-3. Damage Control Assistant	1. Operations Department
s-4. CIC Officer	2. Engineering Department
s-5. Assistant for Disbursing	3. Supply Department
s-6. Communications Officer	

The erasure of a correct answer is indicated in this way on the answer sheet:

	1 T	2 F	3	4
s-3		C		
s-4	C			
s-5			C	
s-6	C			

How To Score Your Immediate Knowledge of Results (IKOR) Answer Sheets

	1 T	2 F	3	4	
1		C	6		1
2	C	9		9	2
3			C		
4	CC	12			1

Total the number of incorrect erasures (those that show page numbers) for each item and place in the blank space at the end of each item.

Sample only

Number of boxes erased incorrectly	0-2	3-7	8-
Your score	4.0	3.9	3.8

Now TOTAL the column(s) of incorrect erasures and find your score in the Table at the bottom of EACH answer sheet.

NOTICE: If, on erasing, a page number appears, review text (starting on that page) and erase again until "C", "CC", or "CCC" appears. For courses administered by the Center, the maximum number of points (or incorrect erasures) will be deducted from each item which does NOT have a "C", "CC", or "CCC" uncovered (i.e., 3 pts. for four choice items, 2 pts. for three choice items, and 1 pt. for T/F items).

Assignment 1

Meet the Construction Electrician: Safety

Textbook NAVEDTRA 10636-H: Pages 1-32

In this course you will demo[illegible] ning has taken place by correctly answering training items. The mere physical [illegible] ing a choice on an answer sheet is not in itself important; it is the mental achiev[illegible] ever form it may take, prior to the physical act t at is important and toward which [illegible] t career course learning objectives are directed. The selection of the correct choice for a course training item indicates that you have fulfilled, at least in part, the stated objective(s).

The accomplishment of certain objectives, for example, a physical act such as drafting a memo, cannot readily be determined by means of objective type course items; however, you can demonstrate by means of answers to training items that you have acquired the requisite knowledge to perform the physical act. The accomplishment of certain other learning objectives, for example, the mental acts of comparing, recognizing, evaluating, choosing, selecting, etc., may be readily demonstrated in a course by indicating the correct answers to training items.

The comprehensive objective for this course has already been given. It states the purpose of the course in terms of what you will be able to do as you complete the course.

The detailed objectives in each assignment state what you should accomplish as you progress through the course. They may appear singly or in clusters of closely related objectives, as appropriate; they are followed by items which will enable you to indicate your accomplishment.

All objectives in this course are learning objectives and items are teaching items. They point out important things, they assist in learning, and they should enable you to do a better job for the Navy.

This self-study course is only one part of the total Navy training program; by its very nature it can take you only part of the way to a training goal. Practical experience, schools, selected reading, and the desire to accomplish are also necessary to round out a fully meaningful training program.

Learning Objective: Identify fundamentals of staffing a Public Works Department.

1-1. On which of the following factors are staffing requirements of a Public Works Department determined?

1. Size
2. Location
3. Mission
4. All of the above

1-2. A CEC officer who heads the operating division of a Public Works Department has the title of

1. shops engineer
2. leader
3. general foreman
4. group superintendent

1-3. Which of the following blue collar titles carries the most responsibility?

1. Snapper
2. Leadingman
3. Quarterman
4. Chief quarterman

Learning Objective: Point out purposes of general ratings and Navy enlisted classifications (NEC's) and identify skills prescribed by NEC's.

1-4. A general rating is used to identify

1. an individual's job qualifications
2. a specialty used in wartime
3. a broad field of related duties
4. an individual's performance in completing his practical factors

1-5 Navy enlisted classifications are designed to make it easy to exercise management control over

1. CEC officers
2. Navy enlisted personnel
3. officers and enlisted men
4. civilian employees of a Public Works Department

In items 1-6 through 1-8, select from column B the Navy enlisted classification that is assigned to reflect the skills in column A.

	A. Skills	B. NEC's
1-6.	Splicing multiconductor cables used in telephone communication and in electric power transmission and distribution systems	1. CE-5632
		2. CE-5642
		3. CE-5644
1-7.	Repairing switchboards, telephones, and automatic PBX and PAX telephone exchange equipment	4. EA-5515
1-8.	Repairing electrical systems of shore-based power plants	

1-9. Which of the following tasks would a person assigned the NEC EA-5515 be expected to perform?

1. Placing underwater demolition charges
2. Supervising the collection of pile-driving test data
3. Supervising the day-to-day operation of the safety department
4. Preparing management data associated with one or more construction projects

Learning Objective: Recognize principles of the advancement system.

1-10. Which of the following is NOT a general requirement to qualify for promotion to CE2?

1. Completion of required training courses
2. Passing a written examination
3. Passing the required performance test
4. Length of time in grade

1-11. Your immediate reward for satisfying all the requirements for advancement is

1. eligibility for promotion
2. actual promotion
3. more prestige
4. more authority and increased responsibility

1-12. Before being transferred to another duty station, you should make sure that your NAVEDTRA 1414/1 is

1. among your personal papers
2. in your service record
3. retained by your division officer
4. destroyed and a new one started at your new duty station

1-13. Which of the courses listed in NAVEDTRA 10052 for the CE rating must a CE2 complete before he is eligible to take a servicewide examination for advancement?

1. All courses listed
2. All courses listed for the next higher rate
3. Asterisked courses listed for the next higher rate
4. Unmarked courses listed for the next higher rate

Learning Objective: Recognize publications for advancement study and point out good study practices.

In items 1-14 through 1-16, select from column B the publication that is the source of the information in column A.

	A. Information		B. Publications
1-14.	Latest edition of a given Rate Training Manual	1.	Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards
1-15.	References used as source material for fleetwide advancement examinations	2.	Bibliography for Advancement Study
1-16.	Skills required of enlisted personnel	3.	List of Training Manuals and Correspondence Courses
		4.	NAVFAC Documentation Index

1-17. Which of the following hints for studying should help you get the most from your Rate Training Manual?

1. Devote your time exclusively to important military topics
2. Try not to cover a complete unit in any one study period
3. Omit easy material; study only the most difficult and the unfamiliar
4. Make notes as you study, particularly of main ideas, then review your notes

1-18. When studying a Rate Training Manual, you should make it a practice to

1. set up a fixed number of pages in each study period
2. relate new information to things you already know
3. memorize as much as you can from a chapter and repeat it to a shipmate
4. concentrate on studying just before an examination so you will not forget important details

1-19. In studying Rate Training Manuals, a reliable indication that you have mastered the subject matter in a chapter is your ability to

1. quote, word for word, passages from the chapter
2. express in your own words the main points of the subject
3. memorize pertinent dates, tables of weights and measures, and other such information
4. ask intelligent questions about the subject

1-20. You can keep abreast of new developments that affect you, your work, and the Navy by

1. obtaining and applying up-to-date information that pertains to your rating
2. collecting personal copies of pertinent technical manuals
3. completing all enlisted correspondence courses that pertain to your rating
4. completing all officer correspondence courses that are related to your rating

1-21. Which of the following publications is published by the National Bureau of Standards?

1. National Electrical Code
2. National Electrical Safety Code
3. Navy Safety Precaution for Shore Activities
4. Advanced Base Electrical Systems

Learning Objective: Recognize safe practices in the use of tools and equipment and identify publications that provide information on electrical safety.

1-22. The extent of body damage caused by electrical shock depends on

1. the size of the body
2. the value of voltage touched by the body
3. the amount of current flow through vital organs
4. whether the current was a-c or d-c

1-23. When the human body is shocked by more than 200 ma of current, the chest muscles contract to clamp the heart.

1-24. Which is the most important factor in rescuing a man in contact with an electric circuit?

1. Preventing physical injury to the man
2. Separating the man from the electric power by the quickest possible means
3. Preventing the victim's body resistance from decreasing
4. Avoiding damage to equipment

1-25. The procedure for discharging a charged capacitor is to discharge it

1. twice for at least 10 seconds each time
2. once for at least 10 seconds each time
3. once for at least 5 seconds each time
4. twice for at least 5 seconds each time

1-26. In what position should your f t, knees, and back be when you are lifting an object?

1. Feet apart 15 inches from object, knees bent, and back straight
2. Feet apart close to object, knees straight, and back bent
3. Feet together and close to object, knees bent, and back straight
4. Feet together 15 inches from object, knees straight, and back straight

1-27. When placing an 8-ft ladder against a wall, how far from the wall should you set the base of the ladder?

1. 1 ft
2. 1 1/2 ft
3. 2 ft
4. 2 1/2 ft

1-28. In climbing a ladder while carrying tools, you should make it a practice to carry the tools

1. in both hands; use no hands for climbing
2. in the right hand; use the left hand for climbing
3. in the left hand; use the right hand for climbing
4. in a bag slung over the shoulder; use both hands for climbing

1-29. Which of the following tasks requires that goggles be worn?

1. Soldering an electrical connection
2. Pouring acid into water
3. Drilling holes in concrete or other masonry materials
4. Each of the above

1-30. Hard hats provide better head protection than ordinary hats. Which of the following is another true statement in favor of wearing hard hats instead of conventional headgear?

1. Hard hats weigh less
2. Hard hats keep the head cooler on hot, sunny days
3. Hard hats keep the neck and ears warmer in cold weather
4. Hard hats stay on the head in high winds without benefit of a chinstrap

1-31. What advice should you give one of your men who objects to wearing a hard hat because it does not keep his head, neck, or ears warm?

1. Wear a stocking cap over the hard hat
2. Wear ordinary headgear made of extra thick material
3. Wear a winter liner
4. Use a chinstrap to keep the hard hat in place

1-32. The wiring specifications contained in NAVFAC Specifications are based on minimum requirements for safe design of electrical installations which the National Fire Protection Association provides in

1. Handbook H-30
2. National Electrical Code
3. National Electrical Safety Code
4. Safety Precautions for Shore Activities

1-33. Handbook H-43 contains engineering data for the installation and maintenance of electrical and communications lines. The name of this publication is

1. Installation and Maintenance of Electrical Supply and Communication Lines, Safety Rules and Discussion
2. National Electrical Safety Code
3. Safety Precautions for Shore Activities
4. Safety Rules for the Installation and Maintenance of Electric Supply and Communication Lines

1-34. When a rubber glove is being air-tested for holes, air is trapped in the glove and forced into the thumb, fingers, and palm of the glove. Any hole through which air can escape is found by

1. submerging the glove in water and watching for bubbles of air to rise to the surface of the water
2. coating the glove with a soapsuds solution and watching for soap bubbles to form
3. Holding the glove to your ear and listening for the sound of escaping air

1-35. Which of the following is a safe practice?

1. Cleaning an electrical apparatus with a flammable fluid
2. Wearing a hard hat when working or walking in an area where hoisting or overhead work is going on
3. Shifting positions of your feet while lifting a heavy object
4. Sharpening gaffs on pole climbers when gaff length measures less than 1 1/4 inches

1-36. Which of the following materials is suitable for covering grounded metal to keep a worker from coming in contact with the metal?

1. Damp plywood
2. Dry canvas that has holes in it
3. Dry insulating material that contains no holes or conductors
4. Dry phenolic material that has a conductor embedded in it

1-37. If it becomes necessary to work on electrical circuits or equipment in wet or damp locations, what is one very important step you should take?

1. Making sure that there is no contact between the wet floor and your shoes
2. Wearing shoes that have thick rubber soles
3. Wiping the area where you are going to stand with a dry rag

1-38. Which of the following actions is an approved method for improvising an insulating barrier between a metal tool and the hand of its user?

1. Applying cambric sleeving covered by several layers of friction tape
2. Applying several layers of friction tape
3. Applying several layers of approved rubber insulating tape (half-lapped) covered by a layer or two of friction tape

1-39. A metal tool handle may be covered with several layers of rubber tape, and then covered with a layer of friction tape for emergency electrical use.

1-40. What should you do if a powder-actuated tool misfires, or fails to fire, after a period of 15 seconds?

1. Open the tool, remove the powder charge, then remove the guard
2. Remove the guard from surface and then remove the charge
3. Replace the charge and then attempt to refire

1-41. If you are called while soldering the connections to a motor and have to leave your shop for a few minutes, what should you do with the hot soldering iron?

1. Display a HOT HAZARD sign and return as soon as possible
2. Leave it plugged in so others will see that it is hot
3. Retin it and leave it plugged in
4. Unplug it and stow it in its assigned storage area

1-42. Which of the following procedures is recommended for cleaning a soldering iron?

1. Hold a cleaning cloth in your hand and wipe the hot iron across it
2. Place a cleaning cloth on a suitable surface and wipe the hot iron across it
3. Swing the hot iron with enough force to remove the solder
4. Tap the hot iron on a metal surface to knock the solder off

1-43. Which of the following measures is considered the final touch in the completion of a high voltage equipment installation?

1. It is checked by the electrical officer
2. It is checked by the division's leading CPO
3. It is tested by an experienced operator
4. High voltage warning signs are posted in full view of operating personnel

1-44. Warning signs are posted in work areas to alert individuals of existing hazards and to prevent damage to machinery.

1-45. What are the ground lead requirements for an electrical workbench that is 8 feet long?

1. One 8-foot ground lead
2. Two 8-foot ground leads
3. Two 4-foot ground leads
4. Three 3-foot ground leads

1-46. Which of the following sizes of ground lead is appropriate for a workbench that is supplied by 12-gage line conductors?

1. 10-gage
2. 14-gage
3. 18-gage
4. 20-gage

1-47. What is the maximum acceptable resistance between an installed grounding object and the earth?

1. 1 ohm
2. 3 ohms
3. 6 ohms
4. 12 ohms

1-48. What is the primary purpose for repainting electrical equipment?

1. To prevent incipient corrosion
2. To improve its appearance
3. To improve the insulation
4. To provide a means of identification

1-49. Portable electric cables should be considered very dangerous if they are

1. more than 10 feet long
2. spliced at any place
3. insulated with any material other than rubber
4. red

1-50. Which of the following procedures apply to portable, electrical personal equipment?

1. Inspection every 6 months
2. Repair and reinspection by the electrical crew, if damaged
3. Certification by means of a Safety Officer's tag of approval before use
4. All of the above

1-51. Assume that the personal radio belonging to one of your men has a built-in power transformer that presumably provides isolation from the powerline, but you have found that the insulation resistance between the metal chassis of the radio and the primary of the transformer is only three megohms. What safety measure do you take?

1. Check the tubes and replace the defective ones
2. Ground the chassis by means of a grounded plug and suitable cord
3. Insert an additional resistance, approximately 100 megohms, in series with the primary of the transformer
4. Reverse the leads to the secondary of the transformer

1-52. Electric shavers do not require 3-prong gounding plugs because the

1. owner cannot use it ashore
2. original cord is fused to the housing to prevent it from being pulled out
3. housing is of nonconductive plastic material and the cutting blades are isolated from the electrical components within the shaver
4. 3-conductor cord is too heavy and bulky which makes it hard to use

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Learning Objective: Recognize safe and unsafe working practices or conditions applicable to energized circuits.

1-53. Which of the following is a safe practice for members of an electrical crew?

1. Wearing rubber gloves with leather overgloves to remove transformer fuses
2. Placing a NAVSHIPS Warning Tag 3950 (3-63) on each switch of a circuit that is being overhauled
3. Placing 2 NAVSHIPS Warning Tags 3950 (3-63) on each supply switch of a circuit that is being repaired by 2 working parties
4. Each of the above

1-54. What is the first step that you should take in replacing a 220-volt 15-ampere fuse?

1. Deenergize the circuit completely
2. Put on rubber gloves before touching the fuse
3. Remove and replace the fuse with insulated fuse pullers
4. Turn the switch off to the burned out fuse only

1-55. What are metal locking devices used for?

1. Locking switches in the ON position to stop them from tripping in case of a surge in power
2. Locking switches in the OFF position to prevent them from being operated accidentally
3. Securing circuits which are no longer in use
4. All of the above

1-56. After the power has been turned off and the switch locked and tagged, you still should not proceed to work on the circuit until you have checked

1. your tools
2. the lights in the space
3. the metering and control circuits
4. the grease and oil fittings

1-57. Which of the following circuit breakers should be secured before work is started on a switchboard?

1. The main circuit breaker to the switchboard
2. The circuit breaker at the generator feeding the switchboard
3. All circuit breakers leading to the switchboard
4. All of the above

1-58. One of the requirements of a rear-service switchboard is that

1. the fuse box be behind the switchboard
2. it must be dusted every day
3. the rear of the switchboard be covered with an expanded metal enclosure
4. it be painted with bright colors to identify the circuits

1-59. Who determines whether or not work is done on an energized circuit?

1. Electrical officer only
2. Damage control officer only
3. Engineering officer only
4. Commanding officer or his authorized representative

1-60. Before work is started on an energized circuit or switchboard, a Construction Electrician should check to make sure that

1. the division officer is present
2. a Hospital Corpsman is present in case of an accident
3. the safety officer is present
4. men are stationed by circuit breakers or switches and telephones are manned

1-61. What is the recommended procedure for discharging high voltage capacitors when checking a circuit?

1. Discharge once with a suitably insulated shorting or grounding bar
2. Discharge at least twice, with a minimum 15-second interval
3. Discharge when the power is turned off and again before starting to work on the circuit
4. Connect a jumper lead across the capacitor leads but be sure to remove it before energizing the circuit

1-62. Which of the following practices must NOT be followed when you are taking measurements on electrical circuits or equipment?

1. Deenergize the equipment after taking the reading
2. Assign the responsibility of energizing the equipment to an assistant standing by the switch
3. Avoid touching the test instrument while the power is on
4. Take the measurement directly by means of flexible leads or probes

1-63. Which of the following is NOT a requirement for working on live conductors and equipment operating at 600 volts or less?

1. Adjacent live or grounded conductors and equipment should be covered with insulating material or approved rubber protective equipment
2. Bare or exposed places on one conductor must be taped or covered before another conductor is exposed
3. Two men should work together
4. One must maintain a body clearance of 2 feet when working on energized lines

1-64. When you are testing a 2,000-volt circuit to determine if it is alive and it is not possible to recheck the voltage detector on a known live circuit, what must you do?

1. Test the voltage detector on a live circuit in the electric shop before work is started
2. Ask personnel who have used the detector if it is working properly
3. Use a new detector
4. Check it two times, each with a different detector

1-65. When working on electrical equipment with operating voltages of 3 to 7.5 kilovolts, 7.5 to 12 kilovolts, or 12 to 33 kilovolts, you should maintain a minimum distance of, respectively

1. one-half foot, 1 foot, and 2 feet
2. one-half foot, 2 feet, and 3 feet
3. 1 foot, 2 feet, and 3 feet
4. 2 feet, 3 feet, and 4 feet

1-66. Under which of the following conditions may work be performed with hot-line tools on lines energized at more than 5,000 volts?

1. Rain is impending but not actually falling
2. Snow is falling but rubber gloves are worn
3. Tools are dry and rubber gloves are not worn
4. All of the above

1-67. The world's most important protective agent is

1. a careful individual
2. a good safety training program
3. use of safety procedures
4. good safety equipment

Learning Objective: Indicate fire control and fire preventive measures.

1-68. The best way to extinguish an electrical fire is to turn off the power and cover the fire with

1. foam
2. carbon dioxide
3. sand
4. water

1-69. How soon after the discharge of a fire extinguisher should you request a recharge or replacement?

1. Immediately
2. After a damage estimate has been made
3. At the next firefighting equipment inspection
4. Within 1 week after the fire

1-70. What should be done with wiping rags and other flammable waste material?

1. Place them in a cardboard box and keep the box behind the motors and generators
2. Place them in a tightly closed metal container and empty the container at the end of each work day
3. Place the rags so they may be reached easily and place other waste material in a tightly closed metal container
4. Remove them from the work area and place them in a neat pile in an open area

1-71. When not in use, volatile solvents should be kept in tightly closed containers and stored in a separate building or in

1. a ventilated fire-resistant room
2. the coolest part of the generator room
3. the supply room
4. an area just outside the generator room but protected from the sun

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Assignment 2

Safety (continued): Blueprints, Diagrams and Schematics; Special Tools

Textbook NAVEDTRA 10636-H: Pages 33-87

Learning Objective: Point out some important aspects of safety training and identify information that must be entered on the Accidental Injury/Death Report, OPNAV Form 5100/1.

2-1. Sound safety training enables a man to guard against hazards for which safety devices are impracticable.

2-2. Which of the following will be most beneficial in reducing accidents?

1. Never work on unfamiliar equipment
2. Memorize all safety precautions
3. Work slowly and deliberately
4. Recognize hazardous situations

2-3. Which of the following measures is the preferred method for making the men in your electrical group safety conscious?

1. Allow them to learn by experience
2. Provide them with safety reminders and your personal example
3. Restrict them if they fail to follow the safety rules
4. Send them to safety school

2-4. Completing the reverse side of an accident report (OPNAV Form 5100/1) provides the crew leader with a guide for

1. summarizing safety lectures and movies that focus on accident prevention
2. recommending action that will help prevent accidents similar to the one being reported
3. describing the type of injury
4. organizing a training program that will emphasize accident preventions

2-5. The main purpose for completing sections 22 and 24 of the Accidental Injury/Death Report, OPNAV Form 5100/1, is to

1. recommend corrective actions
2. identify the principal unsafe condition or act that caused the accident
3. provide a detailed description of the accident
4. determine whether or not a formal investigation of the accident is required

2-6. What kind of information should you supply in section 27 of the Accidental Injury/Death Report, OPNAV 5100/1?

1. Your description of the accident
2. Your opinion as to whether the accident was caused by an unsafe act or not
3. Your opinion as to whether or not the accident was caused by an unsafe condition
4. Your opinion of what can be done or what will be done to prevent accidents like the one being reported

Learning Objective: Indicate injuries encountered in electrical work and recognize procedures for rendering first aid to accident victims.

2-7. As a general rule in aiding accident victims, which type of injury poses the greatest threat to life and requires the most immediate treatment?

1. Stoppage of breathing
2. Wounds, fractures, and dislocations
3. Shock
4. Serious bleeding (hemorrhage)

2-8. One of the symptoms of a person in shock is

1. a weak pulse
2. constracted pupils
3. cold, dry skin
4. deep, fairly regular breathing

2-9. Which of the following is the most important factor in trying to rescue a man from contact with an electric circuit?

1. Securing the circuit quickly
2. Pulling the man away from the circuit quickly
3. Starting artificial resuscitation as soon as possible
4. Avoiding contact with the live circuit or with the victim while he is in contact with it

2-10. What must you do for the victim of electrical shock before beginning artificial respiration?

1. Administer a stimulant
2. Treat him for shock
3. Clear his mouth of foreign matter or other obstruction
4. Cover him with a blanket

2-11. Indications of a cardiac arrest include

1. cold and moist skin, weak pulse at the wrist, and shallow, irregular breathing
2. dilated pupils of the eyes, complete absence of pulse at the wrist, and weak or stopped breathing
3. contracted pupils of the eyes, complete absence of pulse at the wrist, and weak or stopped breathing
4. contracted pupils of the eyes, weak pulse at the wrist, and cold and moist skin

2-12. When giving a cardiac massage, you should place your hands one on top of the other so that the heel of the bottom hand covers the

1. lower part of the breastbone and the fingers of the top hand point toward the victim's neck
2. upper part of the breastbone and the fingers of the top hand point toward the victim's neck
3. lower part of the breastbone and the fingers of the top hand point toward the victim's feet
4. upper part of the breastbone and the fingers of the top hand point toward the victim's neck

2-13. When giving a cardiac massage you should repeat the application of pressure about

1. 40 to 60 times per minute
2. 50 to 70 times per minute
3. 60 to 80 times per minute
4. 70 to 90 times per minute

Information for items 2-14 through 2-20. You are first to arrive at the scene of a fire. You find the following casualties injured as indicated.

Poindexter--right hand and forearm are reddened and blistered.

Anderson--entire left leg exhibits symptoms of increased warmth, tenderness, and a reddish appearance.

Stein--face, neck, and both arms are reddened and blistered; skin on both hands is completely destroyed and the underlying tissue is black.

Laine--burn on his right leg from the knee down, is characterized by complete destruction of the skin, with charring and cooking of the deeper tissues.

2-14. Your main objectives in rendering first aid treatment to burn victims are to

1. prevent infections, relieve pain, and combat shock
2. relieve pain, immobilize the burned areas, and apply antiseptics to the burns
3. combat shock, open blisters, and apply wet antiseptic dressings to the burns
4. remove foreign materials from the burns, apply hot moist packs to the burns, and prevent infections

2-15. The casualty who is most seriously burned is

1. Poindexter
2. Anderson
3. Stein
4. Laine

2-16. The casualty who has only first degree burns is

1. Poindexter
2. Anderson
3. Stein
4. Laine

2-17. Poindexter and Stein are experiencing more pain than Anderson and Laine.

2-18. In treating Stein for shock, what exception should you make to the general procedure of shock treatment?

1. Keeping him cool
2. Giving him liquids by mouth
3. Placing him in a sitting position
4. Giving him 1/2 grain of morphine

2-19. Clothing or other foreign material adhering to a severly burned area of the body should be

1. removed carefully, with a sterile pointed stick
2. soaked loose in warm saltwater
3. cleansed from the area with soap and water
4. left alone

2-20. If battery acid spills on your skin, the first thing you should do is

1. wipe the acid off with a clean, dry rag
2. wipe the acid off with a clean, wet rag
3. rinse the acid away with plenty of cold, fresh water
4. neutralize the acid with ammonia or baking soda

Learning Objective: Define the term blueprint and identify its main part.

2-21. What is the definition of a blueprint?

1. Information extracted from a drawing
2. A reproduction of the working drawing of a schematic
3. A drawing reproduced on blue paper only

2-22. The main part of a blueprint for a machine is the

1. bill of material for the machine
2. title block
3. legend
4. graphic representation of the machine

Learning Objective: Point out procedures to follow in reading and caring for blueprints and identify symbols used on electrical drawings.

2-23. Which of the following is a necessary practice in the proper care of blueprints?

1. They should never be folded
2. They should be kept out of sunlight
3. Only pencil should be used to make notations on them
4. Each of the above

2-24. After refolding a blueprint, you should be able to see its identifying number without having to unfold the print.

2-25. Knowing the drawing number on a blueprint enables you to properly file the print. The drawing number also serves to

1. identify the type of system described in the drawing
2. indicate the overall size of the object described
3. help in locating a drawing referenced on another print

2-26. The quantity, stock number, and description of all items required for a wiring job are listed in which part of the blueprint?

1. Legend
2. Title block
3. Notes
4. Bill of material

2-27. In planning a job, you are working from a drawing and need to know how many feet of conduit to order. Which of the following techniques would give you the most accurate results?

1. Measure the lines on the drawing, and convert them to scale
2. Trace out the conduits on the drawing, then estimate the length of each run
3. Copy the dimensions of conduit from the drawing and add them
4. Refer to the schematic for the job

2-28. What part of a print explains the abbreviations and item numbers shown on the print?

1. Legend
2. Block diagram
3. Title block
4. Scale

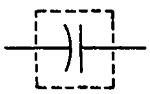
2-29. Assume you are reading an electrical blueprint and do not understand the meanings of various symbols shown. Which of the following standards should you consult to find the meanings of these symbols?

1. Military Standards for Electrical Symbols
2. American National Standard Institute's Standard Y 32.9
3. Each of the above

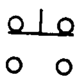
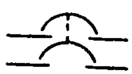
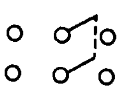
2-30. In learning to read an electrical drawing, you try to see the mental picture that symbols, abbreviations, and notes make.

● Refer to table 3-1 of your textbook when answering items 2-31 through 2-34.

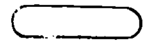
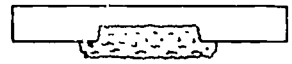
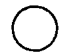
2-31. Which of the following graphic symbols represents a shielded capacitor?

1. 
2. 
3. 
4. 

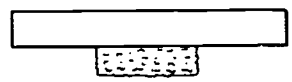
2-32. Which of the following graphic symbols represents a pushbutton two-circuit switch?

1. 
2. 
3. 
4. 

2-33. Which of the following is the standard architectural symbol for a single fluorescent fixture?

1. 
2. 
3. 
4. 

2-34. The architectural symbol for a surface-mounted panelboard and cabinet is

1.
2.
3. 
4.

Learning Objective: Apply electrical diagrams and schematics to internal and external wiring and communications systems.

● The following alternatives are for items 2-35 through 2-37.

A. Schematic diagram

B. Plot plan

C. Wiring diagram

D. Pictorial diagram

2-35. Which type of drawing is helpful in determining where the connections are to be made in an electrical circuit?

1. A
2. B
3. C
4. D

2-36. When used to illustrate a given electrical hookup, which type of drawings would show the same components?

1. A, B, and C
2. A, C, and D
3. B, C, and D
4. A, B, C, and D

2-37. Which type of drawing gives you an idea of what the equipment looks like?

1. A
2. B
3. C
4. D

2-38. Refer to textbook figure 3-5. What is the voltage and phase of the primary mains leading to the battalion's mess hall?

1. 208-volt, 3-phase
2. 240 volt, 1-phase
3. 240 volt, 3-phase
4. 120 volt, 3-phase

2-39. The distribution system of textbook figure 3-6 feeds three phase power to operate the motor pool lighting system and 120-volt motor.

● When answering items 2-40 through 2-42, refer to textbook figure 3-7.

2-40. About how much No. 2 wire will be needed between the pole next to manhole 22 and the pole near building 126?

1. 2,300 ft
2. 2,000 ft
3. 1,500 ft
4. 700 ft

2-41. If each guy wire is made up of 45 feet of 3/8-inch steel cable, how many feet of this cable and how many strain insulators are needed for the job?

1. 180 ft of cable and 8 insulators
2. 225 ft of cable and 10 insulators
3. 270 ft of cable and 10 insulators
4. 270 ft of cable and 12 insulators

2-42. How much of the line poles will be above ground when they are set?

1. 29 ft
2. 35 ft
3. 40 ft
4. 41 ft

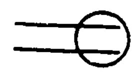
2-43. The dotted lines in textbook figure 3-8 represent

1. fencing
2. underground conduit
3. bonding wire
4. overhead ducts

2-44. Which of the following is the standard architectural symbol for a lighting panel?

1. 
2. 
3. 
4. 

2-45. The architectural symbol for a convenience outlet is

1. 
2. 
3. 
4. 

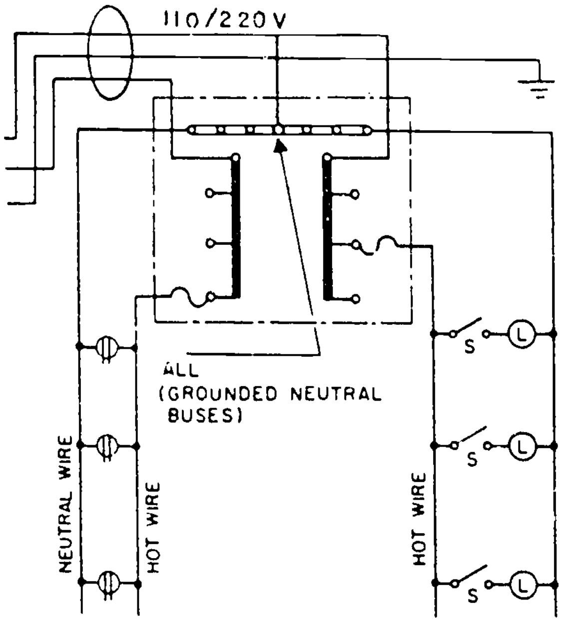


Figure 2A

When answering items 2-46 through 2-48, refer to figure 2A.

2-46. It is possible to run a 220-volt, 3-phase motor from this panel.

2-47. The panel board is equipped to handle six circuits but only two are in use.

2-48. A single switch is used to disconnect power from all the convenience outlets.

2-49. How are P and S of the induction coil placed in series in textbook figure 3-11A?

1. Energizing coil LR1
2. Deenergizing coil LR1
3. Taking the receiver off the hook
4. Closing switch LJ1

2-50. Line lamp LL1 in figure 3-11A is energized

1. when relay LR1 deenergizes
2. when relay LR1 energizes
3. only when the transmitter is deenergized

2-51. You are to install an electric range in the galley. Which of the following best describes the information obtainable from textbook figure 3-12?

1. Each heating coil will be rated at 600 watts
2. Each heating coil will be rated at 300 watts
3. Each heating coil is wired to operate on 230 volts
4. Each range unit should be fused for at least 15 amperes

Learning Objective: Point out advantages, disadvantages, and applications of NAVFAC prepared standard drawings.

2-52. The advanced base drawings in NAVFAC P-437 save construction time because

1. they are easier to use than the normal types of blueprints
2. all buildings constructed by SEABEES are basically the same
3. they permit much work to be done on an assembly line basis when several similar structures are to be built
4. they provide a standard plan for all shop installation

2-53. Which of the following is a disadvantage of the standard drawings prepared by NAVFAC for use at an advanced base?

1. A single master plan cannot be used for all buildings
2. They add to the time it takes to wire buildings for heating and lighting
3. They create more installation problems than they solve
4. They exclude detailed information on proper installation of equipment

2-54. Study the print in textbook figure 3-15. What do the numbers on the 50 ampere, 3-phase panelboard indicate?

1. Circuit breaker mounting bolt sizes
2. The output voltage of each circuit
3. The circuit breaker each circuit ties into from the main panel

2-55. Where on a blueprint would the electrician find information as to special instructions needed to complete an assembly?

1. Notes on the bill of material
2. Notes written in the margins of the print
3. Directly beneath the assembly number

Learning Objective: Identify special tools and fundamentals of operating and caring for them.

2-56. Power tools used by a construction electrician in an NMCB are to be found in the

1. electrician's toolkit
2. lineman's toolkit
3. central toolroom

2-57. The speed of a pneumatic drill is controlled by means of the

1. air compressor
2. throttle valve
3. handle switch
4. feed screw

2-58. The rapid wear of the moving parts of a pneumatic grinder is the result of

1. improper lubrication
2. excessive speed
3. underloading
4. excessive air pressure

2-59. The attachment on a pneumatic pavement breaker for cutting asphalt and frozen ground is a

1. moil point
2. spade
3. chisel point
4. tamper

2-60. Which of the following is a *good* practice in the operation of a pneumatic pavement breaker?

1. Taking bites of 4 to 8 inches behind the working face
2. Taking bites of 4 to 8 inches in front of the working face
3. Drilling holes with the moil point
4. Breaking concrete with the chisel point

2-61. By not shutting off the pavement breaker when the moil point breaks through concrete, you are likely to end up with a broken

1. moil point
2. shank holder
3. shank
4. retainer bolt

2-62. Of the following types of power hacksaws, with which can you increase or decrease the pressure on the material being cut?

1. Hydraulic
2. Mechanical
3. Gravity
4. Feed

2-63. What should be the pitch of a power hacksaw blade for cutting a solid piece of brass stock?

1. 4 teeth per inch
2. 6 teeth per inch
3. 10 teeth per inch
4. 14 teeth per inch

2-64. In operating power-assisted hammers, you will need one piston for pins and another for studs, unless there is a difference in the lengths of the

1. stud shanks
2. stud threads
3. pins
4. spacers

Learning Objective: Identify fundamentals of operating and caring for portable air compressors and power earth augers.

2-65. The pressure drop in air line hose over a long distance is taken care of by the installation of

1. two air compressors in series
2. two air compressors in parallel
3. an air manifold

2-66. Refer to textbook figure 4-21. Which of the following tasks should be performed on an air compressor daily?

1. Change the compressor oil
2. Grease the engine
3. Inpsect the compressor oil filter cartridges
4. Clean the radiator and cooler cores

2-67. Which of the following devices prevents the clutch from being engaged or disengaged while the air compressor engine is running?

1. Shifter mechanism
2. Electric clutch
3. Built-in safety interblock
4. Friction disk

2-68. In starting up an air compressor engine, you can eliminate the warmup steps after the first daily startup.

2-69. Which of the following is an indication that the cartridge of an air cleaner used with a Worthington air compressor needs replacement?

1. A red flag pops up
2. A green flag pops up
3. The aspirator plugs up, sounding an alarm
4. The cartridges plugs up, sounding an alarm

2-70. Which of the following is the reason for the safety statement, "Never use benzene, kerosene or other light oils to clean compressor intake filters, cylinders or air passages"?

1. They form a highly explosive mixture under compression
2. They form a gum and cause parts to wea
3. They form a varnish and will plug up fuel lines
4. They form a varnish and cause the cylinder rings to stick

2-71. Which of the following are routine prestart checkpoints for the earth auger?

1. Oil levels in the engine crankcase and transmission
2. Supply of fuel and hydraulic oil level
3. Coolant and battery water levels
4. All of the above

2-72. After cranking an auger engine for more than 30 seconds, you should wait 1 minute to allow for cooling of the

1 battery
2. starter
3. generator
4. engine oil

2-73. Refer to textbook figure 4-29. The purpose of the spirit level is to

1. level the auger engine
2. level the auger shaft
3. plumb the auger shaft
4. plumb the auger engine

2-74. Support jacks are used to dampen bouncing of the earth auger when it is being operated in hardpan or rocky soil.

Assignment 3

Test Equipment, Control and Protective Equipment

Textbook NAVEDTRA 10636-H: Pages 88-128

Learning Objective: Identify principles and techniques of measuring with an ammeter, voltmeter, megohmmeter, phase sequence indicator, and special purpose testers.

3-1. What does the accuracy of test equipment depend upon?

1. Its design
2. Your test procedures
3. The treatment of the instrument
4. Each of the above

3-2. When measuring an unknown current with an ammeter which is capable of measuring several different ranges, you should make the first measurement with the meter set at

1. the highest range it will measure
2. a range slightly higher than you estimate the current to be
3. the range where you estimate the current to be
4. the lowest range it will measure

3-3. After using the ohmmeter scale of a multimeter, what should you do to guard against discharging the battery in the multimeter?

1. Turn off the multimeter
2. Turn the meter to d-c supply positive
3. Turn the meter to d-c supply negative
4. All of the above

3-4. How must an ammeter be connected in the line to measure current?

1. Across the line
2. In series with the line
3. Parallel
4. Series-parallel with the load and line

3-5. The maximum current-carrying capacity of an ammeter is called its

1. polarity
2. rating
3. calibration
4. current flow

3-6. Which of the following factors would limit the current-measuring capabilities of an ammeter?

1. Size of the instrument
2. Range switch
3. Connecting terminals
4. All of the above

3-7. Why is a shunt sometimes used on an ammeter?

1. To give more accurate readings
2. To create a voltage drop
3. To extend the range of the meter
4. To calibrate frequency

3-8. Which of the following is a difference between the voltmeter and the ammeter?

1. A voltmeter has only one scale; an ammeter has more than one
2. A voltmeter can measure a-c only; an ammeter can measure both a-c and d-c
3. A voltmeter must be connected in parallel with the line; an ammeter is connected in series
4. A voltmeter must be used with a shunt; an ammeter may or may not be used with a shunt

3-9. The presence of three internal resistors in a voltmeter schematic would indicate that

1. the voltmeter is more rugged than a meter with one resistor
2. more protection is provided the meter than to one with one resistor
3. the meter could be used for three times its rated voltage
4. the meter has three voltage ranges and scales

3-10. When measuring voltage less than 600 volts and more than 150 volts, what should you do?

1. Add an external resistor to the meter
2. Add an external shunt to the meter
3. Move the meter selector switch to the highest range
4. Move the meter selector switch to the lowest range

3-11. After hooking up the clamp-on voltammeter (textbook figure 5-9) to read voltage only, you can connect it to read current by clamping its jaws around one of the conductors to the motor and then turn the switch to AMPERES.

3-12. In addition to being used primarily for testing insulation, the Vibrotest megohmmeter can be used to measure

1. alternating and direct current
2. a-c and d-c voltage
3. d-c voltage only
4. power factor

3-13. You are testing a capacitor with a Vibrotest megohmmeter. Six seconds after starting the test, the needle stops moving upward. You can estimate the value of the capacitor to be

1. .04 µF
2. .4 µF
3. 4.0 µF
4. .004 µF

3-14. What is the reason for keeping records of transformer insulation tests?

1. The scheduling of further tests is made convenient
2. No change in insulation resistance indicates properly functioning equipment
3. A gradual deterioration in insulation resistance can be more easily noted
4. Technical publications recommend it

3-15. Refer to textbook figure 5-22. You are instructed to check the phase sequence of an incoming alternator and make the hookup. After connecting the phase sequence meter lead A to X_1, B to Y_1, and C to Z_1, the meter rotates in the counterclockwise direction. When you connect the meter lead A to X, B to Y, and C to Z, the meter rotates clockwise. Which of the following connections are made correct in hooking up?

1. X to X_1, Y to Y_1, Z to Z_1
2. X to X_1, Y to Z_1, Z to Y_1
3. X to Y_1, Y to X_1, Z to Z_1
4. X to Z_1, Y to X_1, Z to Y_1

3-16. The Snap-Around probe used with the Servivar Electrical Tester measures the current flowing in a conductor by means of

1. capacitive pickup
2. Direct contact
3. Heat transfer
4. Transformer action

3-17. Adapters are available which enable the Weston Model 633 Industrial Analyzer type 3 to be used for single- and three-phase, 4 wire measurements.

3-18. The chief function of the MS-1A tester is to measure the

1. amount of power used by a load at a given voltage
2. percent of the load that is shared by each phase of a three-phase power source
3. resistance of protective devices due to corroded contacts
4. time it takes a protective device to open a circuit at a given current

● In answering items 3-19 and 3-20, refer to figure 5-31 of your textbook and assume that you are testing a ground.

3-19. R_1 is adjusted until the currents in what two windings cancel each other?

1. Primary of T_1 and secondary of T_1
2. Primary of T_1 and primary of T_2
3. Primary of T_2 and secondary of T_1
4. Primary of T_2 and secondary of T_2

3-20. The unknown ground resistance is read on

1. M
2. R_1
3. V_1
4. V_2

3-21. What is the maximum permissible resistance between solid earth ground and the lightning arrester ground on a distribution system?

1. 1 ohm
2. 5 ohms
3. 10 ohms
4. 15 ohms

Learning Objective: Recognize the purpose of a Wheatstone bridge and techniques of using the bridge to measure loop resistance of a communications circuit.

3-22. The purpose of the Wheatstone bridge shown in textbook figure 5-34 is to

1. indicate the resistance of a circuit directly in ohms without any need for calculations
2. locate cable faults approximately in communication and power cables by measuring resistance in the cable wires
3. measure the magnitude of the active power in an electric circuit
4. detect the difference in potential between two points of a circuit

● In answering items 3-23 and 3-24, refer to table 5-1.

3-23. When using the Wheatstone bridge to measure a loop resistance of approximately 1,200 ohms, at what position do you set the MULTIPLY BY dial?

1. 1/100
2. 1/10
3. 1/1
4. 10/1

3-24. With the MULTIPLY BY dial on 1/1, you balance the Wheatstone bridge with a reading of 3 on the thousands dial, 8 on the hundreds dial, 3 on the tens dial, and 1 on the units dial. What is the actual resistance in the loop?

1. 38.31 ohms
2. 383.31 ohms
3. 3,831. ohms
4. 38,310. ohms

3-25. When preparing to make a loop resistance test of a pair of conductors with the portable Wheatstone bridge, what connections must you make?

1. Connect the two far ends of the pair of wires together
2. Connect the cable sheath to the ground point
3. Ground one wire and connect it to binding post X_2
4. Reverse the wires connected to line binding posts X_1 and X_2.

3-26. What galvanometer indication tells you that the Wheatstone bridge is balanced?

1. Pointer movement to the left or negative side of the meter and back to zero
2. Pointer movement to the right or position side of the meter and back to zero
3. No deflection of the meter
4. A full scale deflection to either side of the meter

Learning Objective: Recognize principles and applications of the regular Varley loop test, three Varley test, and Murray loop test.

3-27. The objective of a regular Varley loop test is to locate a

1. ground in a high resistance loop when the unbalance is 1 ohm or less
2. ground in a high resistance loop when the unbalance is more than 1 ohm
3. cross in a high resistance loop when the unbalance is more than 1 ohm
4. cross in a high resistance loop when the unbalance is 1 ohm or less

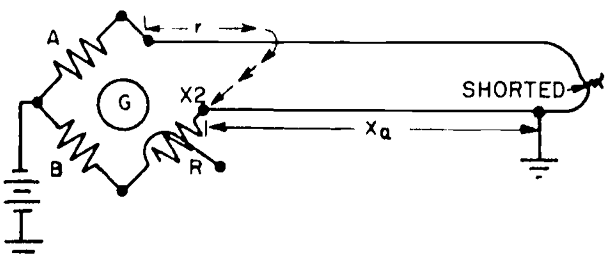


Figure 3A

● To answer items 3-28 through 3-30, refer to figure 3A and apply the formula:

$$Xa = \frac{(r \times B) - (A \times R)}{A + B}$$

3-28. Let $\frac{A}{B} = \frac{1}{1}$. Then R, the decade dial reading of the meter after the loop is balanced will equal

1. loop resistance (r) minus twice the resistance of Xa
2. loop resistance (r) minus the resistance of Xa
3. loop resistance (r) plus the resistance of Xa
4. the resistance of Xa

● In answering items 3-29 and 3-30, use the following information:

Loop resistance = 6,020 ohms (r)
R = 10,510 ohms
A = 1
B = 4
Distance from the test set to the short circuit at the far end of the cable run is 70 miles.

3-29. What is the resistance from test point X_2 to the fault?

1. 1594 ohms
2. 2313 ohms
3. 2714 ohms
4. 3010 ohms

3-30. How far is the fault from binding post X_2?

1. 60.5 miles
2. 61.7 miles
3. 63.1 miles
4. 65.3 miles

3-31. In making a three-Varley test you set the MULTIPLY BY dial on 1/4. To obtain the resistance from the test set to the ground, you multiply the difference between the decade dial readings of the second and third tests by

1. 5
2. 8
3. 3
4. 4

● In answering items 3-32 and 3-33, refer to textbook figure 5-38 and assume that you are using a three-Varley test. You are using the 1/9 range on the MULTIPLY BY dial and you have obtained the following information:

R_1 = 3,500
R_2 = 4,100
R_3 = 9,600

3-32. What is Xa?

1. 270
2. 550
3. 1250
4. 1570

3-33. If the distance to the far end of the cable run is 61 miles, what is the distance to the fault?

1. 27 miles
2. 35 miles
3. 43 miles
4. 55 miles

3-34. If you need to use A/B = 1 and the resistance in the faulty wire is greater than the good wire, what measure do you take to balance the bridge in the Varley 1 test of figure 5-38?

1. Disconnect the good wire
2. Ground the good wire
3. Put a resistance in series with the good wire
4. Use the 1/10 range on the MULTIPLY BY dial

3-35. Assume that you are using the Murray loop test shown in textbook figure 5-39 and you have set the MULTIPLY BY dial at M100. Also, assume that the length of the loop is 30 miles and you have obtained a reading of R = 1,400. Determine the distance: Da (from point X_2 to the ground).

1. 12 miles
2. 16 miles
3. 22 miles
4. 28 miles

Learning Objective: Point out the purpose of the cable repairman's test set I-51, and identify principles of locating a ground in a telephone cable.

3-36. What is the purpose of a cable repairman's test set?

1. To locate faults in PBX connectors, regular connectors, and reverting-call switches
2. To measure the magnitude of the active power in an electric circuit
3. To locate an open circuit in communication and powerlines
4. To locate accurately a short in a cable after its approximate location is determined

3-37. You know or are able to find the following information about a cable that has a fault:

A. The type of fault
B. The resistance of good conductors
C. The resistance of faulty conductors
D. Approximate location of the fault
E. Length of the cable
F. Equipment connected to the cable

Which items of information are essential in pinpointing a cable fault with the cable repairman's test set?

1. A, C, D
2. A, B, E
3. B, D, E
4. D, E, F

Information for items 3-38 through 3-43. Refer to textbook figure 5-42. You are going to use a cable repairman's test set to pinpoint a ground in a 51-pair telephone cable that has been located with a Wheatstone bridge. The ground is solid and concerns one wire only.

3-38. Connections between the test set and the cable are made with a 2-wire test cord. Where do you connect the test cord on the cable end?

1. To the grounded conductors
2. To the grounded conductor and a ground rod
3. To the cable sheath and the grounded conductor
4. To the grounded conductor and a cable clamp

3-39. To what terminals on the test set do you connect the other ends of the test cord?

1. 1 and 3
2. 2 and 3
3. 3 and 4
4. 4 and 5

3-40. If the fault has a resistance of over [illegible]00 ohms, to what test set terminals do you connect the test cord leads?

1. 1 and 3
2. 2 and 3
3. 3 and 4
4. 3 and 5

3-41. How should you hold the exploring coil to locate the ground?

1. Parallel to the cable
2. Parallel to the cable and move it along the cable toward the grounded point
3. At right angles to the cable
4. At right angles to the cable and move it along the cable near the grounded point

3-42. When the exploring coil is right over the grounded point, the tone in your receiver

1. increases
2. disappears
3. increases then decreases
4. decreases then increases

3-43. If the ground is of such high resistance as to make the absolute location uncertain, what is the proper procedure?

1. Make a plainly visible mark at the approximate location and then repeat the tests from the other end of the cable
2. Repeat all of the tests that you made previously
3. Reset the tone switch to position 2 and repeat the tests
4. Reset the tone switch to position 2 and repeat the tests but from the opposite end of the cable

Learning Objective: Identify principles of locating short circuits, crossed wires, and split pairs with the cable repairman's test set.

3-44. How should you locate a short in a paired cable with the cable repairman's test set?

1. Set the tone switch on position 1 and connect the test cord to the two faulty wires
2. Set the tone switch on position 2, connect the test cord to the two-faulty wires, and use the exploring coil
3. Use a test cord containing three insulated wires and connect them to three separate cable wires
4. Set the tone switch on position 2 but do not use the exploring coil

3-45. Refer to figure 5-46 in the textbook. In what way does the locating of crossed wires differ from the locating of a grounded wire in a paired cable?

1. The tone switch is set on position
2. The test cord is connected to terminals 3 and 4 on the tone unit
3. The exploring coil is held at right angles to the cable
4. The exploring coil is not used

3-46. Refer to textbook figure 5-48. In locating a split pair, what procedure must you follow at the far end of the cable that is under test?

1. Connect the two wires that are split
2. Connect the split pairs to ground
3. Short out the four wires involved
4. Disconnect the four wires involved and make sure none of them is in contact w[illegible] another

3-47. For your initial tracing of a cable to locate a split pair, you have both conductors of one pair connected to the test cord leads. After you pass the exploring coil over the point locating the split pair, the volume of the tone you hear through the receiver will

1. increase only
2. decrease only
3. increase and decrease
4. be steady

3-48. In the alternate method of locating a split pair, one conductor of each pair is connected to the test cord leads. After you pass the exploring coil over the split, the volume of the steady tone you hear through the receiver will

1. increase only
2. decrease only
3. increase and decrease
4. stop momentarily, then remain steady

3-49. You are testing for a wet spot in a cable. After the exploring coil passes over the wet spot, the volume of the tone you hear through the receiver will

1. increase only
2. decrease only
3. increase or decrease
4. neither increase and decrease

3-50. There are two methods of connecting the tone unit of the test set to a cable for tracing a wet spot. In one of these methods, the two leads in the test cord are connected to

1. one wire in each of two pairs of wires
2. two groups of wire, selected at random, and strapped together
3. two wires selected at random
4. one wire, selected at random, and the cable sheath

Learning Objective: Identify procedures and techniques of locating and tracing buried communication cable with the cable repairman's test set.

3-51. You are using the cable repairman's test set I-51 and component parts necessary for tracing buried cable. How can the tone volume be increased when the exploring coil is connected directly to the receivers via a terminal strip?

1. By increasing the source voltage in the test set
2. By connecting an amplifier between the exploring coil and the receivers
3. By changing the tone switch from position 1 to position 2
4. By changing the test leads from the high resistance lugs to the low resistance lugs at the set

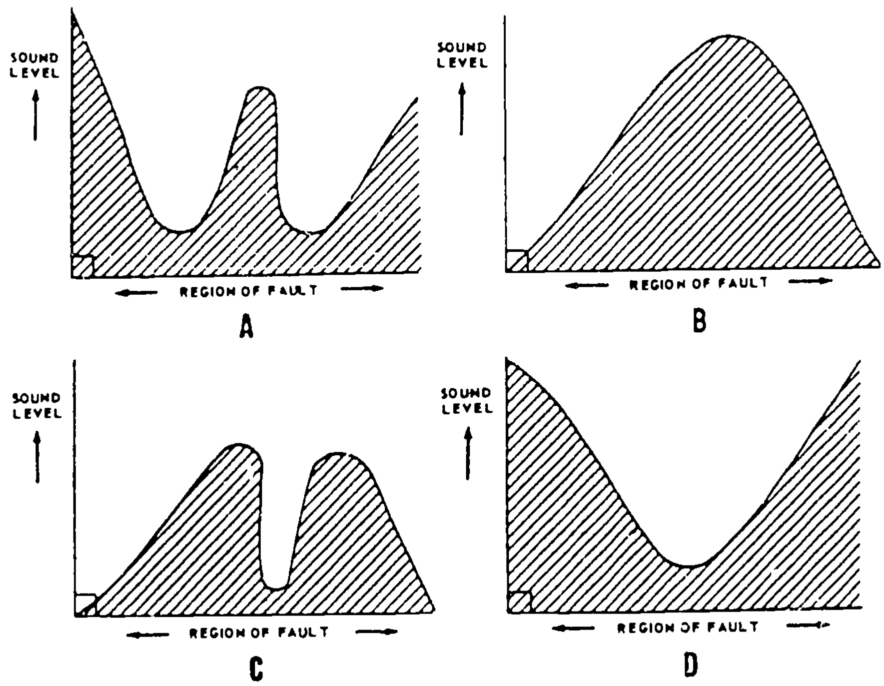


Figure 3B

3-52. You are using the stray current method of tracing a buried cable. Which of the graphs in a figure 3B illustrates the change in sound as you approach, and then pass over the cable?

1. A
2. B
3. C
4. D

3-53. The induction from a nearby powerline precludes the use of stray current to trace a buried cable. An alternate method for tracing the cable involves the use of current from a

1. ducter ohmmeter
2. power circuit analyzer
3. Wheatstone bridge
4. cable repairman's test set

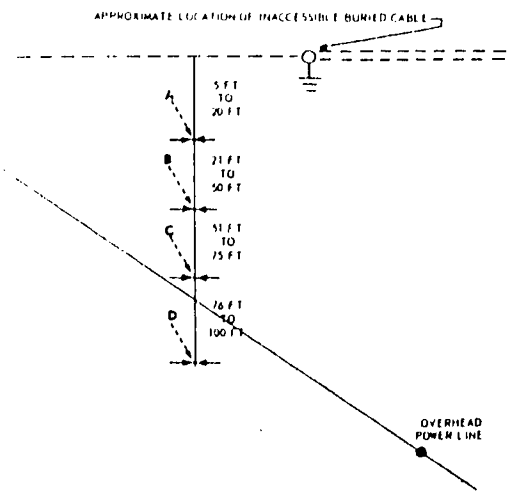


Figure 3C

3-54. At which point should the nearest ground rod be located from the buried cable in figure 3C?

1. A
2. B
3. C
4. D

3-55. While attempting to locate the vicinity of a buried cable with test set I-51, you should start by holding the exploring coil in what position?

1. Horizontal and parallel to the cable
2. Vertical and parallel to the cable
3. Perpendicular to the cable

3-56. Assume that you have found the general location of a cable with test set I-51. What type of tone will indicate the exact location of the cable if the exploring coil is held in the horizontal position and passed over the cable?

1. A steady rise in tone until maximum tone is received
2. A steady rise in tone and then a sharp decrease in tone
3. A tone that changes from constant to pulsating
4. A tone that changes from low pulsating to high constant

Learning Objective: Identify operating principles and techniques of the telephone test set AN/PTM-5 and the Tela Cable Model 262 test set.

3-57. The purpose of the telephone test set (AN/PTM-5) is to

1. identify single leads or pairs in a cable without breaking the individual conductor insulation
2. identify single leads or pairs in a cable without breaking or opening the outer sheath
3. locate open or shorted leads in a cable without breaking individual conductor insulation
4. locate open or shorted leads in a cable without disturbing the position of the conductors

3-58. In what position should the probe tip be held when you are checking conductor pairs with the telephone test set?

1. Between the pair, nearly parallel to the conductors
2. Between the pair, at right angles to the conductors
3. Across the pair, at right angles to the conductors
4. Squeezed tightly against the pair with the fingers

3-59. How are grounds indicated on the Tela Cable Model 262?

1. Shorted light goes out
2. Indicating light comes on
3. Indicating light flashes
4. Shorted light flashes

3-60. Before identifying a certain wire in a cable with a Tela Cable test set, an operator must have

1. an assistant standing by to deenergize the circuit
2. an assistant at the point where the cable is terminated
3. the circuit energized
4. the circuit deenergized

Learning Objective: State the purpose of electrical protective devices and indicate techniques of locating common faults in fused circuits.

3-61. The purpose of electrical protective devices is to

1. govern the amount of power delivered to any electrical load
2. prevent power interruptions
3. prevent short circuits
4. prevent dangerous amounts of power in a circuit

3-62. In locating the cause of trouble in a defective circuit, the first thing you should do is to

1. test the circuit with a voltage tester
2. trace the wiring
3. disconnect the black and white wires from the source of power
4. check the circuit for visible signs of trouble

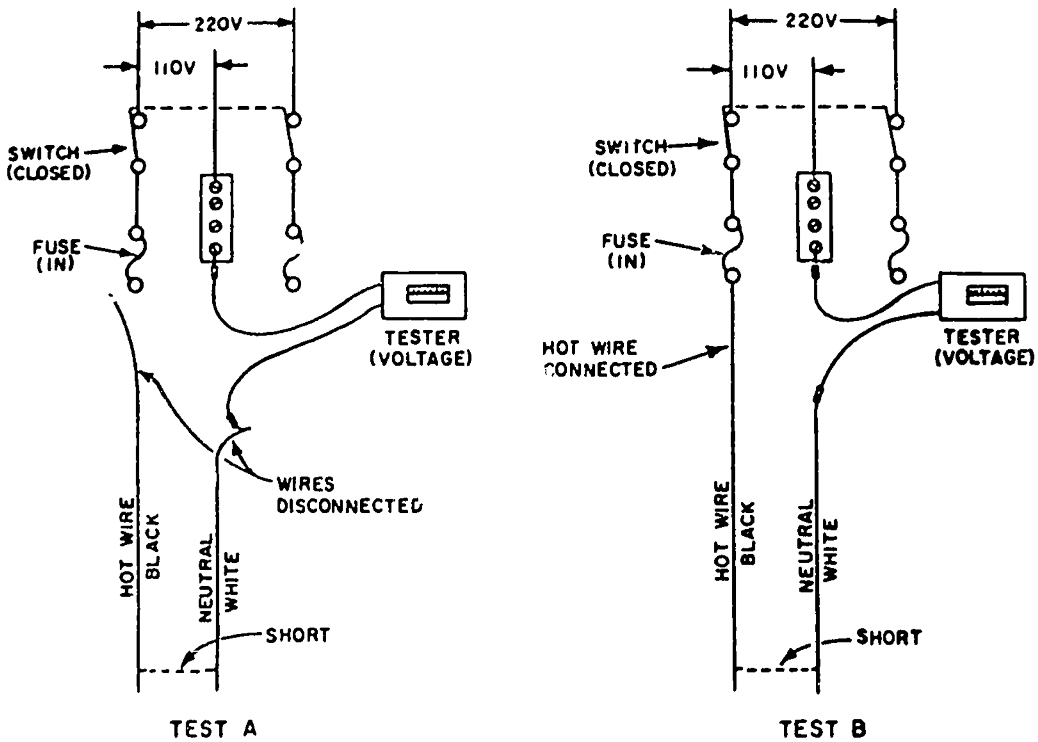


Figure 3D

3-63. Figure 3D illustrates how you can use a voltage tester to test for a short circuit. The circuit has a short if the tester shows

1. a reading when you make test A
2. a reading when you make test B
3. readings when you make tests A and B
4. no readings when you make test A or B

● When answering 3-64 and 3-65, assume that now you are trying to locate a fault in a single-phase 2-wire circuit.

3-64. Before you begin any work on the circuit, you must make sure that

1. the switch is opened and all fuses are removed
2. the hot wire is disconnected at the fuse box when an open circuit is suspected
3. the hot wire is disconnected at the fuse box when a short circuit is suspected
4. both wires are disconnected at the fuse box

3-65. In disconnecting and connecting the wires from the terminals in the fuse box, you should disconnect the

1. hot wire first and connect it first
2. neutral wire first and connect it first
3. neutral wire first and connect the hot wire first
4. hot wire first and connect the neutral wire first

Learning Objective: Recognize operating principles and applications of fuses and circuit breakers.

3-66. What components in a substation, in addition to feeder line breakers, protect transmission lines from the effects of short circuits?

1. Low voltage feeder breakers
2. Low voltage feeder fuses
3. High voltage circuit breakers
4. High voltage fuses

3-67. Fuses combined with gang-operated air-break switches are safe to use with transformers having a capacity of

1. 3,750 kVA
2. 6,000 kVA
3. 7,500 kVA
4. 10,000 kVA

3-68. What action takes place in or is initiated by an expulsion type primary cutout fuse when a serious overload occurs?

1. A second fuse is cut into the circuit
2. A high resistance is placed in series with the load
3. The fuse resets itself
4. The fuse link melts and opens the circuit

3-69. Suppose that in an automatic reset repeating cutout, the first and second fuses blow but the third fuse does not. There is reason to believe that this situation was caused by a

1. short circuit in one of the distribution transformers
2. permanent open in the transmission line
3. temporary fault in the distribution system
4. source generator with an excessive voltage output

3-70. Oxidation on a fuse or fuse clip is an indication of poor contact between the fuse and fuse clip.

3-71. Sections of electrical circuits in substations are often conveniently made safe to work on by

1. installing circuit breakers at important wire junctions
2. placing several more generators than are needed in the substation
3. installing all circuit cables in parallel
4. placing the high voltage circuits underground

3-72. What causes an electrically operated air circuit breaker to open when an excessive current flows through it?

1. A fusible link melts, causing a coiled spring to open the contacts
2. An electromagnet forces the contacts open
3. An electromagnet trips a release mechanism allowing a coiled spring to push the contacts open
4. Current through a high tension spring causes it to expand and open the contacts

3-73. The main contacts of high current circuit breakers are not burned when they open or close due to the

1. bypass action of the arc contacts
2. quenching action of the arc quencher section
3. actions of the bypass contacts and the arc quencher section
4. magnetic field which flows under the arc runner

Assignment 4

Control and Protective Equipment

Textbook NAVEDTRA 10636-H: Pages 128-174

Learning Objective: Indicate procedure for maintaining and inspecting power circuit breakers.

4-1. What must you do before servicing a circuit breaker?

1. Wipe off the surface of the circuit breaker mechanism
2. Direct air from an airhose in order to remove dirt or dust from the mechanism
3. Deenergize all circuits including control circuits to which the breaker is connected
4. Look for corrosion of pins and bearings

4-2. Before working on fixed-mounted circuit breakers, what switches should you open?

1. All switches in the entire switchboard circuit
2. All generator circuit breakers
3. All switches ahead of the breakers
4. All bus tie switches

4-3. Assume that inspection of copper circuit breaker contacts reveals a blackened surface. What is the correct maintenance procedures for these contacts?

1. Wipe the black copper oxide off the contacts with a clean cloth
2. Sand the contact surfaces with fine sandpaper
3. Wipe the contact surfaces with inhibited methyl chloroform
4. Each of the above, if necessary

4-4. Which of the following is most likely to cause a relay magnet to chatter?

1. Burned contacts
2. Open coils
3. Rusty magnet sealing surfaces
4. Shorted coils

4-5. When manually operated circuit breakers normally remain in an open or clogged position over a long period, how often should they be tested?

1. Twice a year, or more often
2. Once each year
3. Once every 2 years
4. Once every 5 years

4-6. Assume that you installed a circuit breaker in the spring of last year. Its first overhaul is due no later than

1. spring of this year
2. fall of this year
3. spring of next year
4. fall of next year

4-7. The first thing that you must do before overhauling a circuit breaker that is in use is to

1. ground the equipment
2. remove all fuses
3. warn people who are using the circuit
4. notify the electrical supervisor of your plans

4-8. Your are cautioned NOT to trip the contact mechanism of an oil circuit breaker after the contacts are lifted from the oil in order to

1. facilitate the finding of damaged parts
2. minimize the possibility of rust forming on the contacts
3. avoid electrical shock
4. prevent mechanical shock damage to breaker parts

4-9. If paper tank liners in oil circuit breakers have absorbed moisture, the liners should be dried by

1. baking them in an oven
2. placing them in the sunshine
3. blowing air on them with a fan
4. storing them in a cool room

4-10. How can the CE tell when the thickness of a circuit breaker contact has fallen below the required minimum?

1. By consulting minimum contact thickness tables in the manufacturer's instructions
2. By taking 1/2 of the original thickness as stated in the manufacturer's instructions
3. By applying a general rule tying replacement to years of usage
4. By using the figures stamped on the breaker frame

4-11. What type of contacts do radial-blast interrupters have?

1. Arcing
2. Rolling
3. Butt
4. Sliding

4-12. How much metal can be burned off contacts or radial-blast interrupters before it becomes necessary to replace them?

1. 1/32 in.
2. 1/16 in.
3. 3/32 in.
4. 1/8 in.

4-13. The usual maintenance for the main contacts of cross-blast interrupters consists of

1. applying a light coat of oil to the contacts
2. replacing damaged contacts
3. cleaning and aligning contacts
4. turning the contacts slightly to expose a raw surface

4-14. The arc contacts of a power circuit breaker should be replaced when they become

1. badly pitted or burned
2. slightly discolored
3. brittle
4. bent

4-15. Which of the following is an acceptable method of determining the condition of arc contacts in power circuit breakers?

1. Remove the arc chutes and observe the condition of the arc contacts
2. Without removing any part of the breaker, observe the arc contacts with a dentist's mirror
3. Disassemble the entire breaker and observe the arc contacts
4. Observe the condition of the arcing tips and assume that the condition of the internal contacts is the same

4-16. How often is it recommended that oil in oil circuit breakers be tested?

1. Every 3 months
2. Twice each year
3. Annually
4. Every 3 years

4-17. The oil in power circuit breakers must be filtered until the oil has a minimum dielectric strength of

1. 18,000 V
2. 22,000 V
3. 26,000 V
4. 30,000 V

4-18. When oil from circuit breakers is being tested for dielectric strength, the spacing between standard disks in the tester should be

1. 0.01 in.
2. 0.10 in.
3. 0.15 in.
4. 0.20 in.

4-19. You are checking the condition of the oil in power circuit breakers. Which of the following signs is an indication that the oil must be filtered and tested for dielectric strength?

1. Carbonization
2. Dirt
3. Moisture
4. Each of the above

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4-20. The recommended agent for cleaning external surfaces of power circuit breaker bushings is

1. a dry rag
2. soapy water
3. oil
4. an emery cloth

4-21. What cleaning agent is recommended for removing dust and carbon inside a magnetic airblast circuit breaker?

1. A dry rag
2. Soapy water
3. Oil
4. An emery cloth

4-22. What is the recommended method of preventing moisture from collecting in a magnet airblast circuit breaker?

1. Wiping dry with a rag frequently
2. Cleaning with a solvent regularly
3. Installing air blowers in the breaker compartment
4. Installing heaters in the breaker compartment

4-23. What is the recommended maintenance for treating burned contacts of large trip coils in oil circuit breakers?

1. Replacing the contacts
2. Readjusting the contact airgap
3. Reducing the current through the contacts
4. Cleaning with fine sandpaper

4-24. The speed of the closing motor of an oil circuit breaker is varied by means of

1. an auxiliary control breaker
2. a variable line switch
3. a variable resistor
4. a variable inductance coil

4-25. Infrequent operation is a cause of contacts overheating in power circuit breakers. One way to overcome the overheating problem is by

1. replacing the breaker with another having a large current rating
2. reducing the operating voltage to the contact relay
3. adjusting the closing relay
4. replacing copper contacts with new silver-to-silver contacts

---

Learning Objective: Identify operating principles of magnetic and thermal overload relays.

4-26. What is the best recommended method of overcoming burnout of the operating coil of electrically operated breakers caused by an operator holding the control switch closed too long?

1. Lubricating the mechanism
2. Installing an auxiliary switch
3. Replacing the damaged coil
4. Putting a sign on the switch to remind the operator

4-27. Which of the following actions should you take to remedy the failure of an a-c controlled power circuit breaker to latch closed?

1. Adjust closing relay
2. Test rectifier
3. Install larger incoming wire
4. Charge battery

4-28. When an overload occurs in a magnetic type relay, the increased flux around the coil will lift the iron plunger into the center of the coil.

4-29. The current at which a magnetic overload relay trips may be increased by

1. lowering the dasnpot
2. raising the dashpot
3. adding oil to the dashpot

4-30. A thermal overload relay will finally open the contacts when the

1. heater coil reaches a specific temperature
2. splitter arm moves
3. solder melts
4. tube assembly rotates

4-31. A thermal overload relay is adjusted to trip at a predetermined value of overload current by

1. changing the relative position of the contacts
2. raising and lowering the dashpot
3. rotating the splitter arm
4. moving the relay heater coil

Learning objective: Identify fundamentals of operation of phase-failure and reverse-current relays and principles of grounding.

4-32. When two or more d-c generators are connected in parallel, what device is used to disconnect a generator from the line if the generator starts drawing power from the line?

1. Thermal type relay
2. Reverse-current relay
3. Magnetic type relay
4. Reverse power relay

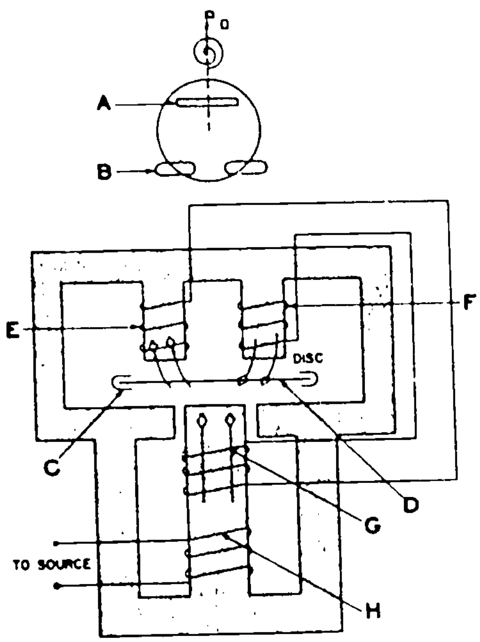


Figure 4-A

In answering items 4-33 and 4-35, refer to figure 4A.

4-33. Oscillations in the induction disk of the timer element of the relay are damped by

1. A
2. B
3. D
4. E

4-34. What must take place to cause reverse rotation of the disk?

1. The polarity of coil G must reverse with respect to the polarity of coil H
2. The polarity of coil E must reverse with respect to the polarity of coil F
3. The current through coils G and H must reverse with respect to the polarity of coils E and F
4. The current through coils E and F must reverse with respect to the polarity of coil H

4-35. The phase-failure relay is actuated when

1. current in the d-c relay coils exceeds current in the reactor coils
2. current in any one of the d-c relay coils is less than in any of the other coils
3. current in one pair of d-c relay coils is less than current in another pair
4. current is reversed through any of the rectifier bridge units

4-36. What is the basic difference, if any, between a system ground and an equipment ground?

1. System ground is the grounding of non-current-carrying metal parts while equipment grounding is the grounding of the hot side of the equipment
2. System ground is the grounding of one of the current-carrying conductors and equipment ground is the grounding of noncurrent-carrying metal parts of a wiring system
3. There is no difference except equipment ground protects personnel and system ground protects equipment
4. There is no difference; both grounds are designed to protect personnel

4-37. NAVFAC requires grounds to be provided in accordance with the National Electrical Code except that individual transformer and lightning arrestor grounds must not be above 10 ohms to ground.

[illegible]

4-38. [illegible] the term "plugging" [illegible]

1. [illegible]
2. [illegible]
3. [illegible] speed
4. [illegible] direction [illegible]

4-39. [illegible]

1. [illegible] and fuses
2. [illegible] circuit breaker
3. [illegible] thermal element
4. [illegible] breaker [illegible]

4-40. The primary function [illegible] controller [illegible]

1. [illegible]
2. [illegible] low voltage
3. [illegible] high voltage
4. [illegible] low voltage

4-41. In the [illegible] three-phase push-button across-the-line starter discussed in the text, the main contacts are closed by the

1. latching relay
2. magnetic coil
3. holding contact
4. thermal relay

4-42. What part prevents the main contacts of a 3-phase magnetic across-the-line starter from closing while the starter is deenergized?

1. An electrical switch which opens
2. An interlock lever
3. A switch behind the stop button on the stop-start station
4. A mechanical latch, operated by a latching relay

4-43. In a 3-phase magnetic across-the-line starter, what [illegible] the overload relay contacts to open?

1. Start-stop station
2. Operating coil
3. Heating element
4. Holding contact

4-44. In a primary resistor controller, what path does current to the motor take after the line contactor closes?

1. Through parallel circuits consisting of the starting resistor and the accelerating contacts
2. Through series circuits consisting of the starting resistors and the accelerating contacts
3. Through the line contactor directly to the motor
4. Through the main line contacts and the starting resistors

4-45. If a wound rotor motor utilizes a secondary resistor controller, the motor is brought up to full running speed by using

1. less and less resistance in the line by steps until the motor is running full speed
2. resistance in parallel across the lines to reduce the voltage until the motor is running full speed
3. the main contacts in parallel with the starting resistors
4. a circuit like the one in a primary resistor controller but without accelerating contacts

● To answer items 4-46 and 4-47, refer to figure 4-10 of your textbook.

4-46. Which of the following conditions of the F and R contactors causes line contacts R1, R2, and R3 to close?

1. F_A open
2. F_A closed
3. R_A open
4. R_A closed

4-47. The F and R contactors are prevented from both being closed at the same time by

1. a mechanical interlock
2. a 10-ampere control fuse
3. the F and R contactor coils
4. the overload relays

4-48. One advantage of an autotransformer starter is that

1. the motor is connected to the line voltage at all times
2. it utilizes capacitors and transformers in parallel to raise starting current
3. high starting line currents can be reduced more than with resistor starters
4. it can be utilized for starting loads that are heavy enough to require resistor starters

[illegible]

[illegible]. What [illegible] of the following [illegible]

[illegible]

[illegible]. [illegible] to [illegible]

1. [illegible] the transformer from the circuit
2. prevent the starting [illegible] M from being energized when the motor is connected directly across the line
3. [illegible] the holding [illegible] circuit [illegible] the main starting coil
4. prevent contact [illegible] from closing when the running contact or coil MR is being energized

[illegible]. How does controller star delta starting of a motor result in first applying 57.7 percent and later 100 percent of line voltage to the motor?

1. Relays cut two different values of resistance into the line leads
2. A star connection is tied to a delta connection in the controller
3. The motor is started on a delta winding connection and later is changed to star connection
4. Windings of a motor having delta connections are changed to star connections at first and later back to delta connection

[illegible]. Which of the following restrictions is placed upon the use or installation of [illegible] cabinets?

1. [illegible] not be used for [illegible] controller circuits
2. They may not be mounted within three feet of the motor they control
3. [illegible] be painted [illegible] certain [illegible]
4. They need not be grounded separately

[illegible]. Which of the following [illegible] be [illegible] parts?

1. [illegible] brush
2. Vacuum cleaner
3. [illegible] solvent
4. Carbon tetrachloride

[illegible]. The most common cause of controller contacts welding together is

1. dirty contacts
2. weak springs
3. high current
4. low voltage

4-57. A type of controller contact recommended for overcoming frequent welding of contacts is the

1. butt contact
2. knife blade contact
3. silver contact
4. carbon contact

4-58. A type of contact used on heavy duty controller equipment that remains closed for extended periods is the

1. silver contact
2. copper contact
3. carbon contact
4. aluminmum contact

4-59. The minimum value of controller contacts falls within the range of

1. 0.015 to 0.020 in.
2. 0.015 to 0.030 in.
3. 0.020 to 0.030 in.
4. 0.020 to 0.040 in.

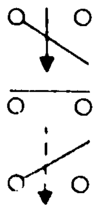
4-60. Wet controller magnet coils should be dried out by

1. baking them in an oven
2. standing them in a warm room
3. sending current through them
4. letting them lie in the sunshine or under a sun lamp

Learning Objective: Identify symbols for manually and electronically operated switches.

4-61. Which of the following symbols represents a switch that is closed by a timing device?

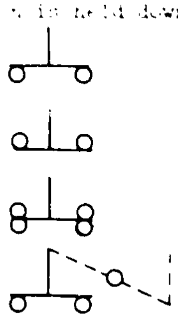
1.
2.
3.



4. Each of the above

4-62. Which of the following symbols represents a pushbutton switch whose only function is to deenergize a circuit when the pushbutton is held down?

1.
2.
3.
4.



Learning Objective: Identify operating principles of photoelectric control relays, limit switches, pressure-and temperature actuated switches, and automatic boiler controls.

4-63. The phototube type of light sensitive cell generates enough energy to operate the photocell relay directly.

4-64. A self-generating photronic cell should operate within what limits of current to be a useful control device for street lighting?

1. 2 to 6 mA
2. 2 to 6 A
3. 1 1/2 to 6 mA
4. 1/2 to 6 mA

4-65. Why are limit switches used in a circuit?

1. To ensure that the equipment operator is within safe physical limits
2. To prevent overloading of the motor circuit
3. To prevent overloading of the control circuit
4. To ensure proper operation of equipment within safe electrical limits

4-66. To actuate the contact mechanism, bellows-type, temperature-actuated switches depend on

1. expansion of metal in the bellows
2. expansion of gas or vapor in the sensing bulb
3. expansion of gas or vapor in the bellows
4. pressure on the helical tube

4-67. Assume that a pressure switch closes at 300 psi and opens at 50 psi. After you make certain adjustments, the switch closes at 350 psi and opens at 50 psi. What kind or kinds of adjustments did you make?

1. Range only
2. Differential only
3. Temperature
4. Range and differential

4-68. To ensure accurate adjustment of thermal switches, it is necessary to

1. compensate for different rates of temperature changes
2. allow a minute or two for the unit to reach the temperature of the surrounding air, gas, or liquid
3. make adjustments very slowly while the switch is in operation
4. check operation of the switch through an entire cycle after making the initial adjustment

4-69. A change in the water level caused by an imbalance of fluid flowing into and out of the steam generating equipment is detected by a level control or float control which causes other devices to either restore the balance or cut off the fuel supply.

4-70. Basically, the purpose of the pressure [illegible] switch is to

1. [illegible] water pressure generated in the boiler [illegible] by cutting off the supply of water from the pumps
2. [illegible] the steam pressure [illegible] by [illegible] the firing cycle of the burner
3. adjust the pressure screw [illegible] the [illegible] that work against the differential adjusting spring
4. react directly to the water pressure generated by the pumps by cutting off the current to them when the proper pressure is reached

4-71. [illegible], the [illegible] switch consists of a [illegible] helix, a mounting frame, an electrical switch, and a

1. [illegible] plate and guide
2. mounting bracket with accompanying screws and washers
3. shaft carrying a contact-making mechanism
4. [illegible] contact and shaft

4-72. The photoelectric combustion control commonly works on the principle that the

1. cell's signal to the relay is reduced
2. relay when properly activated closes the circuit to the burner
3. relay when properly activated opens the circuit to the burner
4. burning flame's luminosity amplifies the cell's signal to make contact within the cell which, in turn, operates the relay

4-73. Which of the following electrical devices has the same function as the photoelectric combustion control?

1. Photoconductive combustion control
2. Pressure limit switch
3. Protectorelay
4. Pyrostat

4-74. Why is the protectorelay used as an electromagnetic switch on many firetube type boilers?

1. To tie together the burner operating controls and the safety combustion controls
2. To provide an interlock between the burner and burner controls
3. To cause emergency shutdown of the burner in response to safety combustion controls
4. To perform all of the above

Assignment 5

Shopwork

Textbook NAVEDTRA [illegible]-B: pages [illegible]

Identify principles of organizing an electrical shop and distinguish between good and poor shop practices.

5-1. The electrical repair shop should NOT be used as a

1. general headquarters for repair and maintenance of electrical equipment
2. storeroom for electrical parts for repair equipment
3. storage depot for the conduit and wire to be used in new construction on the jobsite
4. storeroom and issue room for tools used for electrical equipment repair and maintenance

5-2. When a shopman receives repair parts, such as ball bearing assemblies, he should make it a practice to

1. place them in storage without disturbing their wrappers
2. inspect them to ensure they are of the proper size and in good condition, then store them
3. inspect the, treat with preservative, and then store
4. store them near the euipment on which they may be needed

● To answer items 5-3 through 5-6, determine whether an item describes a good shop practice or a poor shop practice. Erase block 1 on the answer sheet to indicate a good practice; erase block 2 to indicate a poor practice.

5-3. To keep from damaging repair parts, you leave them in their original containers until ready to use.

5-4. When mixing an electrolyte, you pour the acid into the water.

5-5. You wear gloves on both hands when filling a blowtorch with fuel.

5-6. Before starting to work around a rotating machine, you remove your finger rings and wrist watch.

5-7. All Navy installations must ground some appliances. Local authorities may decide not to ground others. The supply voltage that represents the division between the two classes of appliances is

1. 50 v
2. 100 v
3. 150 v
4. 200 v

5-8. Which of the following electrical appliances must have their cases or enclosures grounded?

1. Food mixers
2. Record players
3. Soldering irons
4. All of the above

Learning Objective: Recognize techniques of disassembling a generator or motor and repairing commutators and collector rings.

5-9. Assume that you are sent out to a substation to repair a 3-phase a-c generator that is inoperative. To save yourself time and labor, your first effort toward repairing the generator should be to explore the possibility that the source of the trouble is a

1. sudden change of atmospheric conditions
2. defective manufactured part
3. neglected routine maintenance action
4. poor housekeeping habit

5-10. In breaking down an a-c generator into its component parts, you should use a rawhide or rubber mallet in order to

1. withdraw the rotor
2. work the end bells out of the frame
3. mark the end bells and the frame
4. remove the bolts holding the end bells in place

5-11. After removing semisealed ball bearings from motor end b...s, which of the following actions should you take?

1. Use an approved cleaning solvent on the bearings before storing them
2. Store the bearings in a piece of clean waxed paper until they are ready to be reinstalled
3. Be careful to apply pressure only to the outer race
4. Each of the above

5-12. You should wear canvas gloves when removing a rotor from a generator to prevent the keyways from

1. scratching the field coils
2. nicking the pole pieces
3. scoring the commutator bars
4. cutting your fingers

5-13. A blue or green discoloration on the copper surfaces of a commutator should be removed with a

1. grinding resurfacer
2. dressing tool
3. lintfree cloth dipped in approved solvent
4. strip of canvas moistened with light oil

5-14 What step should you take just before resurfacing pitted collector rings with a commutator stone dressing tool?

1. Clean the collector rings with a solvent
2. Polish the collector rings with oiled canvas
3. Let the generator cool off
4. Run the generator under load

5-15. When turning a commutator on a lat..., how can you keep from twisting the bars?

1. Use a cutting depth of 0.01 inch or less
2. Run the lathe slower than the rated speed of the generator
3. Run the lathe faster than the rated speed of the generator
4. Use a feed of 0.10 ipm

5-16. Which of the following tools should you use to remove any insulating mica that protrudes from slots between commutator bars?

1. A power-driven flexible-shaft undercutter
2. A slotting tool
3. A cutter improvised from a hacksaw blade
4. Each of the above

5-17. When measuring the air gap at the commutator poles to determine the amount of commutator wear or misalinement, how many points of reference should you measure on the stator with respect to a single reference point on the rotor?

1. Five
2. Two
3. Three
4. Four

5-18. The surface of a commutator c... be cleaned with a

1. canvas wiper only
2. canvas wiper or a toothbrush
3. toothbrush or a strip of fine sandpaper
4. strip of fine sandpaper or a canvas wiper

5-19. Pitting caused by electrolytic action on the surface of collector rings can be prevented by

1. reversing the polarity of the rings every few days
2. changing the brushes every few days
3. checking the rings often and changing them when they become worn
4. polishing the rings with a crocus cloth

Learning Objective: Identify practices in maintaining and replacing brushes on d-c motors and generators.

5-20. The grade of brush used in a motor or generator is determined by the

1. size of the motor or generator
2. load and speed of the motor or generator
3. time in service

5-21. Brushes should be replaced when they are worn to within

1. 1/8 inch of the metallic part, or more than 75 percent of the original length of the brush
2. 1/8 inch of the metallic part, or more than 50 percent of the original length of the brush
3. 1/4 inch of the metallic part, or more than 75 percent of the original length of the brush
4. 1/4 inch of the metallic part, or more than 50 percent of the original length of the brush

5-22. You can calculate brush pressure by

1. dividing the brush contact area by the spring pressure
2. subtracting brush contact area from the spring pressure
3. dividing the spring pressure by the brush contact area
4. subtracting the spring pressure from the brush contact area

5-23. When seating a brush, you should use a brush seater and

1. emery paper
2. a file
3. sandpaper
4. an oilstone

5-24. When seating a brush, you should place the sandpaper between the brush and the commutator with the rough side toward the

1. commutator and pull the sandpaper in the opposite direction of normal commutator rotation
2. commutator and pull the sandpaper in the direction of normal commutator rotation
3. brush and pull the sandpaper in the opposite direction of normal commutator rotation
4. brush and pull the sandpaper in the direction of normal commutator rotation

5-25. The finishing steps you take to complete the job of seating the motor brush include

1. turning the sandpaper over, sandpapering again, and touching the seater to the heel of the brush for a second or two
2. touching the seater to the commutator for one or two seconds, vacuuming the dust that results, and cleaning the commutator
3. lifting the brush, inserting the seater between brush and commutator for a second or two, and cleaning the commutator
4. pulling a finer strip of sandpaper between brush and commutator once or twice, vacuuming the dust that results, and cleaning the commutator

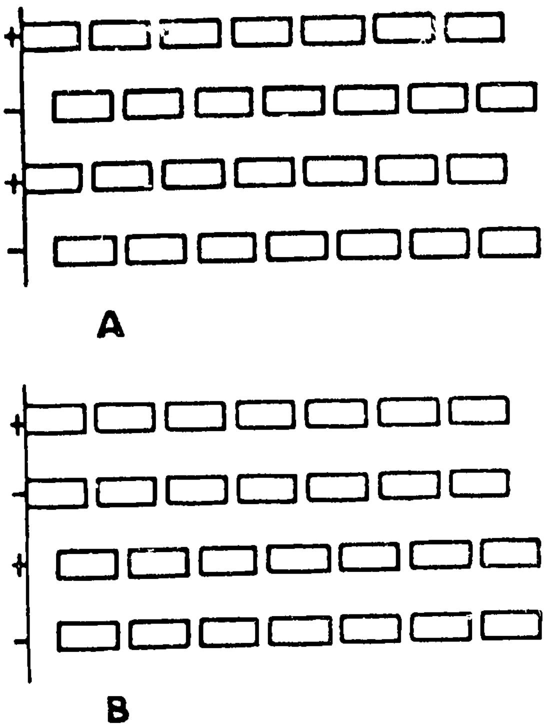


Figure 5A

5-26. Are the brushes in A and B of figure 5A staggered correctly or incorrectly?

1. The brushes in both A and B are staggered correctly
2. The brushes in both A and B are staggered incorrectly
3. The brushes in A are staggered correctly, but the brushes in B are staggered incorrectly
4. The brushes in A are staggered incorrectly, but the brushes in B are staggered correctly

5-27. Brushes may be set on the no-load neutral point of a commutator by the mechanical method or by the reversed rotation method. In either method the brushes are positioned on the commutator at a point where minimum voltage is induced between the

1. adjacent commutator bars
2. commutator and main-field pole
3. commutator and armature
4. commutator and windings

Learning Objective: Identify principles and practices in the maintenance and repair of generator or motor ball bearings and armatures.

5-28. The type of bearing used in motor construction is primarily thrust or radial, depending mainly on whether the

1. rotor rotates clockwise or counterclockwise
2. motor is mounted vertically or horizontally
3. drain holes on the bearing housing are accessible or not
4. bearing housing is, or is not, disassembled to renew bearing grease

5-29. Watch personnel should be familiar with the normal operating temperature of generator bearings in order to detect any sudden change in bearing oil temperature.

5-30. When pressing a bearing onto a shaft, you must apply pressure to what part of the bearing?

1. Cage
2. Raceway
3. Inner ring
4. Outer ring

5-31. What kind of solder do you use for soldering banding wire?

1. Pure lead solder
2. Pure tin solder
3. Lead-alloy solder
4. Tin-alloy solder

5-32. One method of determining what type of winding an armature has is to measure the variations in the resistance found at different places around the commutator. You can read this difference on a low-reading ohmmeter or use a milliammeter connected

1. parallel with a rheostat and a 6-volt battery
2. parallel with a rheostat and a 12-volt battery
3. in series with a rheostat and a 6-volt battery
4. in series with a rheostat and a 12-volt battery

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5-33. On a simplex wave winding the maximum ammeter reading will be indicated when the probes are placed on commutator segments that are approximately how far apart?

1. One pole pitch
2. Two pole pitches
3. Three pole pitches
4. Four pole pitches

5-34. Blue sparks that pass around the armature of a running machine indicate an open armature coil. The sparking occurs because, as the segment to which the open coil is attached passes under a brush, the brush

1. opens and closes a circuit
2. burns the coil insulation
3. shorts out the coil
4. grounds the coil

5-35. In the bar-to-bar test, measurements are taken with which of the following instruments?

1. Milliammeter
2. Millivoltmeter
3. Ohmmeter
4. Each of the above

5-36. Which of the following voltmeter readings indicates a real ground in a d-c armature?

1. Low voltage before and after rotation of the armature
2. Low voltage before rotation of the armature, and normal voltage after rotation
3. Normal voltage before rotation of the armature, and low voltage after rotation
4. Normal voltage before and after rotation of the armature

5-37. How will the voltmeter in textbook figure 7-30 read for open simplex armature coils and for shorted simplex armature coils?

1. Minimum for both open and shorted coils
2. Maximum for both open and shorted coils
3. Minimum for open coils and maximum for shorted coils
4. Maximum for open coils and minimum for shorted coils

5-38. Assume that the test shown in textbook figure 7-30 reveals voltmeter readings that increase or decrease and are alternately positive and negative. What is indicated by such readings?

1. A short in a simplex winding
2. A short in a duplex winding
3. An open in a simplex winding
4. An open in a duplex winding

5-39. During a growler test, you hold a hacksaw blade directly over the top slot of the armature to test for a/an

1. grounded coil
2. shorted coil
3. opened coil

5-40. Assume that you are making emergency repairs to a d-c motor that has a short-circuited armature coil. In order to keep the motor in service until the coil can be replaced you will have to

1. disconnect the coil at one end only
2. cut the coil at one end, then install jumper between this end and the other end of the coil
3. cut the coil at both ends and install a jumper between the risers from which the coil was disconnected

5-41. Before stripping an armature you must record the initial winding data. After recording the data, your next step is to

1. disconnect and remove the coils
2. perform a bar-to-bar test to determine what type winding it has
3. remove the banding wires
4. unsolder the coil leads from the commutator

5-42. The armature wiring should be tested for grounds, opens, or shorts after the coil ends are soldered to the commutator segments.

5-43. When do you put shrink rings on a commutator?

1. After the armature has been baked
2. Before the armature has been baked
3. After the commutator has been tightened
4. Before the commutator has been tightened

In answering items 5-44 and 5-45, refer to textbook table 7-2.

5-44. Silk immersed in oil can be used as insulation on what class of insulation system?

1. A
2. B
3. F
4. H

5-45. What classes of insulation material are considered fragile and should be handled with care?

1. B and F
2. F and H
3. H and N
4. B and N

5-46. The maximum number of times that the windings should be dipped and baked during varnishing is

1. five
2. two
3. three
4. four

5-47. Refer to textbook table 7-3. A high-potential test can be made on a d-c generator when the rewinding is complete and the insulation resistance has been measured and found to be higher than 1 megohm in the

1. armature alone
2. armature circuit less the armature
3. complete armature circuit
4. complete shunt field circuit

5-48 In performing the high-potential test you maintain the full voltage required for 1 minute. Then you should reduce the voltage to one-quarter of the correct value within

1. 10 seconds
2. 15 seconds
3. 20 seconds
4. 25 seconds

Learning Objective: Indicate principles of troubleshooting field coils and stator coils.

5-49. An open circuit in the field winding of a d-c generator that is carrying a load will be indicated by

1. excessive armature current
2. heavy sparking
3. loss of load and voltage
4. stalling of the generator

5-50. Coils are classified as shunt field coils or series and commutating field coils, with one difference being that the former consists of many turns of fine wire while the latter consists of few turns of heavy wire.

5-51. You can discover and locate an open a-c stator winding by taking resistance readings of the

1. coil ends
2. phase terminals
3. interpoles
4. phase terminals, then the coil ends

5-52. After you have rewound stator coils and taped them with insulation, you tin the free ends of each coil. Your next step is to test for

1. continuity and grounds
2. shorted turns and grounds
3. continuity and shorted turns

5-53. The trouble that shorts an entire pole-phase group can be readily located by means of

1. an ammeter
2. an ohmmeter
3. a compass test
4. a balanced-current test

5-54. The balanced-current test is made with

1. an industrial analyzer
2. a low voltage d-c source
3. an ohmmeter

Learning Objective: Identify principles and techniques of maintaining motors and generators.

5-55. A motor that stalls while starting or fails to start probably has a

1. worn bearing
2. grounded winding
3. faulty centrifugal switch
4. burned-out winding

5-56. Why does the accumulation of dirt, moisture, and oil in generator and motor ventilation ducts cause local or general overheating?

1. Resistance to the dissipation of heat is decreased
2. Resistance to the dissipation of heat is increased
3. Moisture and dirt form a nonconducting paste
4. Oil and dirt form a nonconducting paste

5-57. The accumulation of iron particles on motor or generator windings is particularly harmful, because the particles will puncture insulation as a consequence of being

1. removed with a dry rag
2. agitated by magnetic pulsations
3. disturbed by air circulating through the windings
4. absorbed by moisture or oil

5-58. Suction cleaning of motors and generators is preferred to other methods because it lessens the possibility of damage to the

1. insulation
2. commutator
3. brushes
4. soldered parts

5-59. When blowing dust from a 25-kw generator with compressed air, you must be sure to use which of the following?

1. Clean dry air
2. A suction blower at an opening opposite the air jet
3. Air pressure of less the 30 psi
4. All the above

5-60. What substance can be used in an emergency as a cleaning solvent for electrical equipment?

1. Water
2. Alcohol
3. Benzine
4. Carbon tetrachloride

5-61. What is the efficiency and toxicity of trichloroethylene as compared to type II dry cleaning solvent?

1. Toxicity is less and efficiency is greater
2. Efficiency is less and toxicity is the same
3. Toxicity is greater and efficiency is greater
4. Toxicity is less and efficiency is less

5-62. Which of the following safety precautions should you take when using a solvent for cleaning electrical equipment?

1. Have a fire extinguisher on the scene for immediate use
2. Use safety type portable lights if additional lighting is required
3. Remove vapors with exhaust fans or portable blowers
4. All of the above

5-63. By what means are shaft currents kept from flowing through the outboard bearing of a generator on which the bearing pedestal is insulated from the base and the bearing oil piping?

1. Insulating shims under the pedestal
2. Insulated holddown bolts and dowels
3. Insulated couplings in the bearing inlet and outlet oil piping flanges
4. All of the above

5-64. What technique should you use to clean oil and dirt from uncoated copper contact surfaces?

1. Varnishing
2. Sandpapering
3. Silver polishing
4. Moistening with an approved solvent

5-65. New motors or generators are delivered from the manufacturer with the grease cups removed from the bearing housing and replaced with pipe plugs. Where should the grease cups for the new motors or generators be?

1. With the responsible maintenance personnel
2. With the onboard repair parts or special tools
3. With the other grease cups in the workshop or toolroom

5-66. Where should grease cups for a motor be kept when they are not being used to grease bearings?

1. In the workshop or toolroom in the custody of responsible maintenance personnel
2. In a bag attached to the motor
3. On a wire attached to a pipe plug
4. On a wire attached to the motor

5-67. In the absence of other instructions, at what level should you maintain the oil in an oil-lubricated, ball bearing motor housing?

1. Approximately level with the top of the bearing
2. Almost level with the bearing inner ring at the lowest point
3. Level with the center of the bearing
4. Approximately level with the highest point of the bearing inner ring

5-68. To what extent should you run a motor while adding grease to the motor bearings?

1. Intermittently
2. Continuously
3. 3 minutes
4. 10 minutes

5-69. Bearings that require a silicone grease lubricant normally operate at a minimum temperature of

1. 82° C
2. 82° F
3. 90° C
4. 90° F

5-70. Why is it a rare practice to take air gap measurements on ball bearing machines?

1. Machine construction prevents bearing wear
2. Machine construction assures bearing alinement
3. Air gaps are too large to measure with a feeler gage
4. Air gaps are too small to measure with a feeler gage

5-71. Assume that you are taking air gap measurements on a six-pole d-c generator. Which of the following measurements should you take if one end (A) is accessible and the accessibility of the other end (B) is difficult?

1. At ends (A) and (B), 2 measurements spaced approximately 90°
2. At end (B), 6 measurements spaced approximately 60°; at end (A), 2 measurements 90° apart
3. At end (A), 4 measurements spaced approximately 90°; at end (B), 2 measurements 90° apart

5-72. Assume that you are filling the oil labyrinth of a ring-oiled sleeve bearing that is fitted to a 3/4-inch armature shaft. The bearing housing is not fitted with an overflow gage or an oil filter gage. You have filled the labyrinth to the proper height when the oil ring dips into the oil to a depth of approximately

1. 3/8 in.
2. 1/2 in.
3. 3/4 in.
4. 1 1/2 in.

5-73. Which of the following separates the bearing surface from the rotating journal?

1. An oil seal
2. The bearing housing
3. An oil film
4. An opening at the top of the bearing

5-74. At what maximum temperature can sleeve bearings and the outer races of ball bearings be allowed to operate?

1. 90° C for sliding contact bearings
2. 120° C for rolling contact bearings on class A insulated motors
3. 150° C for rolling contact bearings on class H insulated motors
4. 120° C for rolling contact bearings on class B insulated motors

5-75. In case an attachment plug has no cord-grip, you tie an Underwriter's knot in the cord to

1. adapt the plug to fit a 2- or 3-slot outlet receptacle
2. eliminate tension on the terminal connections in the plug
3. ground the connected equipment properly

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