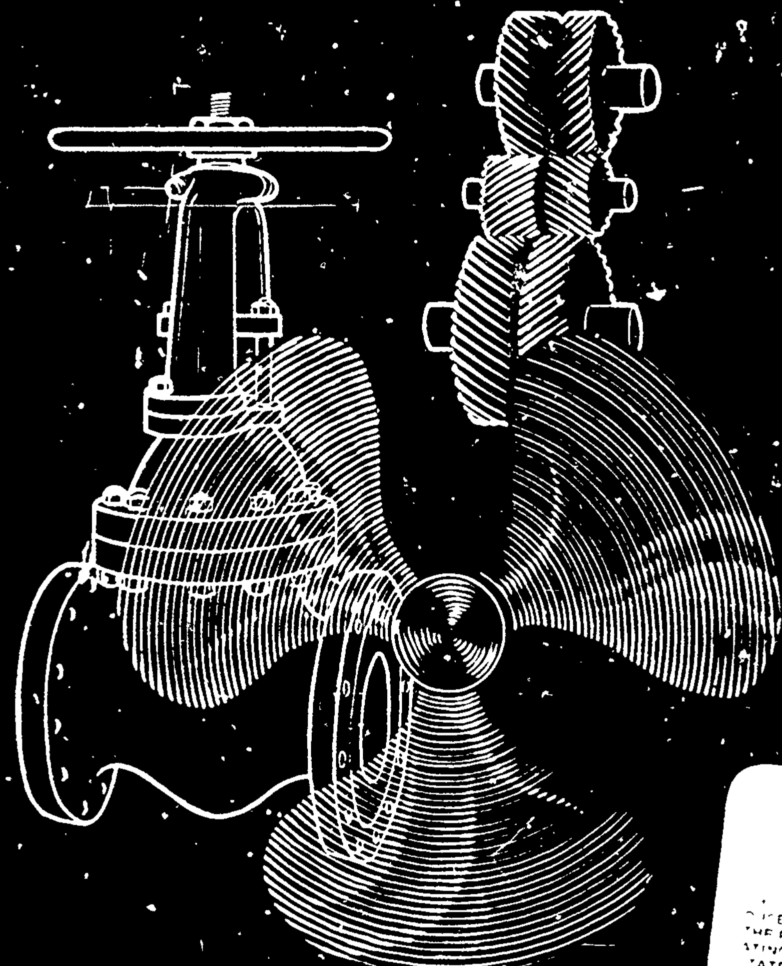


MACHINIST'S MATE 1 & C

NAVAL EDUCATION AND TRAINING COMMAND

RATE TRAINING MANUAL **NAVEDTRA 10525-D**

DOCUMENT RESUME

ED 106 658 | CE 003 855

TITLE	Machinist's Mate 1 and C: Rate Training Manual.
INSTITUTION	Naval Training Command, Pensacola, Fla.
REPORT NO	NAVEDTRA 10525-D
PUB DATE	74
NOTE	213p.
EDRS PRICE	MF-$0.76 HC-$10.78 PLUS POSTAGE
DESCRIPTORS	Air Conditioning Equipment; Equipment Maintenance; Instructional Materials; *Job Training; *Machine Repairmen; *Manuals; *Mechanical Equipment; Military Training; *Seamen; Technical Education; Technical Occupations; Trade and Industrial Education; Vocational Education

ABSTRACT

The rate training manual covers the duties required to efficiently operate and maintain ship propulsion machinery and associated equipment and to maintain applicable records and reports. Chapters cover: turbines; reduction gears; steam-driven generators; heat exchangers and air ejectors; pumps; piping and valves; distilling plants; refrigeration and air conditioning; auxiliary equipment; administration, supervision, and training; propulsion plant efficiency; engineering casualty control; inspections and trials; ship repair; and records and reports. A four-page index is included. (Author/JR)

PREFACE

The primary purpose of training is to produce a combat Navy which can guarantee victory at sea. This victory is dependent upon the readiness of the personnel aboard. Each individual is assigned tasks to perform to satisfy the needs of the ship. The information in this manual relates to tasks required to meet shipboard needs–tasks that are assigned to personnel aboard ship, serving as a Machinist's Mate First Class and Chief Machinist's Mate. This rate training manual covers the duties required to efficiently operate and maintain ship propulsion machinery and associated equipment and to maintain applicable records and reports so that the ship will be able to perform its assigned mission. It is only when we have personnel aboard who can and do perform these tasks efficiently that we will have each ship operating at a high state of readiness and contributing to victory at sea. When you are assigned duties aboard ship as an MM1 or MMC, you will be expected to know the information contained in this manual. The degree of success of the Navy will depend in part on the ability you possess and the manner in which you perform your assigned duties.

Machinist's Mate 1 & C, NAVEDTRA 10525-D 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 Naval Sea Systems Command, the Naval Development and Training Center, San Diego, California, and the Service School Command, Great Lakes, Illinois.

Stock Ordering No.
0502-LP-052-6260

Pevised 1974

Published by
Naval Education and Training Support Command

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON, D.C.: 1974

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.

CONTENTS

CHAPTER 1

INTRODUCTION

At this stage in your naval career, you are well aware that training, on a continuous basis, is essential if you are to reach your desired goals and if the mission of the Navy is to be successfully accomplished. The purpose of this manual is to serve as one of the sources of information as you continue your training to become proficient in the tasks you will be required to perform at the E-6 and E-7 levels of your rating. A knowledge of the information in this manual combined with the essential practical experience should help you in learning to perform assigned tasks and accept greater responsibilities.

INCREASED RESPONSIBILITIES

As you attain each higher promotional level in your rating, you as well as the Navy benefit. The fact that you are using this training manual indicates you have found personal satisfaction in developing your skills, increasing your knowledge, and getting ahead in your chosen career. The Navy has benefited and will continue to do so as you become more valuable as a technical specialist in your rating and as a person who can supervise and train others thus making far reaching and long lasting contributions to the success of the Navy.

In large measure, the extent of your contribution to the Navy depends upon your willingness and ability to accept increasing responsibilities as you advance. When you assumed the duties of a MM3, you began to accept a certain amount of responsibility for the work of others. With each advancement, you accept an increasing responsibility in military matters and in matters relating to the occupational requirements of the Machinist's Mate rating.

You will find that your responsibilities for military leadership are about the same as those of petty officers in other ratings, since every petty officer is a military person as well as a technical specialist. Your responsibilities for technical leadership are special to your rating and are directly related to the nature of your work. Operating and maintaining the ship's main propulsion plants and auxiliary equipment is a job of vital importance, and it's a teamwork job; it requires a special kind of supervisory ability that can only be developed by personnel who have a high degree of technical competence and a deep sense of personal responsibility.

Certain practical details that relate to your responsibilities for engineroom and equipment spaces, administration, supervision, and training are discussed in chapter 11 of this training manual. At this point, let's consider some of the broader aspects of your increasing responsibilities for military and technical leadership.

YOUR RESPONSIBILITIES WILL EXTEND BOTH UPWARD AND DOWNWARD. Both officers and enlisted personnel will expect you to translate the general orders given by officers into detailed, practical on-the-job language that can be understood and followed even by relatively inexperienced personnel. In dealing with your juniors, it is up to you to see that they perform their work properly. At the same time, you must be able to explain to officers any important needs or problems of the enlisted men.

YOU WILL HAVE REGULAR AND CONTINUING RESPONSIBILITIES FOR TRAINING. Even if you are lucky enough to have a highly skilled and well trained engineroom or auxiliary force, you will still find that training is necessary. For example, you will always be responsible for training lower rated men to advancement. Also, some of your best workers may be transferred and inexperienced or poorly trained personnel may be assigned to you. Or a particular job may call for skills that none of your personnel have. These and similar problems require you to be a training specialist who can conduct formal and informal training programs to qualify personnel for advancement and who can train individuals and groups in the effective execution of assigned tasks.

YOU WILL HAVE INCREASING RESPONSIBILITIES FOR WORKING WITH OTHERS. As you advance to MM1 and then to MMC, you will find that many of your plans and decisions affect a large number of people, some of whom are not in the engineroom and some of whom are not even in the engineering department. It becomes increasingly important, therefore, to understand the duties and responsibilities of personnel in other ratings. Every petty officer in the Navy is a technical specialist in his own field. Learn as much as you can about the work of other ratings, and plan your own work so that it will fit in with the overall mission of the organization.

AS YOUR RESPONSIBILITIES INCREASE, YOUR ABILITY TO COMMUNICATE CLEARLY AND EFFECTIVELY MUST ALSO INCREASE. The basic requirement for effective communication is a knowledge of your own language. Use correct language in speaking and in writing. Remember that the basic purpose of all communication is understanding. To lead, supervise, and train others, you must be able to speak and write in such a way that others can understand exactly what you mean.

A second requirement for effective communication in the Navy is a sound knowledge of the Navy way of saying things. Some Navy terms have been standardized for the purpose of ensuring efficient communication. When a situation calls for the use of standard Navy terminology, use it.

Still another requirement of effective communication is precision in the use of technical terms. A command of the technical language of the Machinist's Mate rating will enable you to receive and convey information accurately and to exchange ideas with others. A person who does not understand the precise meaning of terms used in connection with the work of his own rating is at a disadvantage when he tries to read official publications relating to his work. He is also at a great disadvantage when he takes the written examinations for advancement. Although it is always important for you to use technical terms correctly, it is particularly important when you are dealing with lower rated men; careless use of technical terms is likely to be very confusing to an inexperienced man.

YOU WILL HAVE INCREASED RESPONSIBILITIES FOR KEEPING UP WITH NEW DEVELOPMENTS. Practically everything in the Navy—policies, procedures, equipment, publications, systems—is subject to change and development. As a MM1 and even more as a MMC, you must keep yourself informed about all changes and new developments that might affect your rating or your work.

Some changes will be called directly to your attention, but others you will have to look for. Try to develop a special kind of alertness for new information. Keep up to date on all available sources of technical information. And, above all, keep an open mind on the subject of propulsion plants and associated equipment. New types of propulsion plants are constantly being designed and tested, and existing types of propulsion plants are subject to modification.

As you prepare to assume increased responsibilities at a higher level, you need to be familiar with (1) the military requirements and the occupational qualifications given in the *Manual of Qualifications for Advancement*, NAVPERS 18068-C (with changes); (2) the Record of Practical Factors, NAVEDTRA 1414/1; (3) appropriate Rate Training Manuals; and (4) any other material that may be required or recommended in the current edition of the *Bibliography for Advancement Study*, NAVEDTRA 10052. These materials and their use are discussed in *Military Requirements for Petty Officers 1 & C*, NAVEDTRA 10057-C, and *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D. Other sources of information are described later in this chapter.

THE MACHINIST'S MATE RATING

The Machinist's Mate rating is a general rating; there are no service ratings.

Machinist's Mates operate and repair a wide variety of equipment. Those who are assigned to the engineroom (M division), operate and maintain the ship's main engines and associated equipment such as: pumps, distilling plants, compressors, valves, oil purifiers, heat exchangers, governors, reduction gears, and main shafts and shaft bearings.

Machinist's Mates who are assigned duties other than in enginerooms, maintain and repair machinery such as: steering engines, anchor windlasses, cranes, winches, elevators, laundry and galley equipment, and air conditioning and refrigeration equipment. Machinist's Mates also perform duties in the generation, stowage, and transfer of some industrial gases.

Machinist's Mates are assigned to all types of steam-driven surface ships, and the nature of the duties of a particular MM will depend largely on the type of ship to which he is assigned. The duties of a Machinist's Mate assigned to a tender or repair ship may consist mainly of repairs and services to other ships assigned to the tender or repair ship. A Machinist's Mate may choose a specialized area such as air conditioning and refrigeration or the manufacture of industrial gases. These two fields require special training which he may get in the appropriate schools.

Duty at most shore stations is related to training in your field of specialization. You may be assigned as an instructor either at one of the schools or at a recruit training station. To qualify for instructor duty, you must successfully complete a course in instructor training.

Other assignments ashore may include attaché duty and recruiting duty.

NAVY ENLISTED CLASSIFICATION CODES

The Machinist's Mate rating is a source of a number of Navy Enlisted Classification Codes (NECs). NECs reflect special knowledge and skill in certain ratings. The NEC Coding System is designed to facilitate management control over enlisted skills by accurately identifying billets and personnel. It also helps ensure maximum skill utilization in distribution and detailing. There are a number of NECs that may be earned by Machinist's Mate by satisfactorily completing an applicable course of instruction at a specified Navy school. More detailed information regarding the job description of the individual NECs can be obtained by consulting the *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

REQUIREMENTS FOR ADVANCEMENT

In general, to qualify for advancement you must:

1. Have a certain amount of time in grade.
2. Complete the required military and occupational training manuals.
3. Demonstrate the ability to perform all the PRACTICAL requirements for advancement by completing the Record of Practical Factors, NAVEDTRA 1414/1.
4. Be recommended by your commanding officer.
5. Demonstrate your KNOWLEDGE by passing a written examination based on (a) the military requirements for advancement and (b) the occupational qualifications for advancement.

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

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

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

A change in promotion policy implemented the High Quality Bonus Point Factor (HQP). Under this policy, a man who passed the examination but was not advanced can gain points promotion in his next attempt at the examination. Up to 1.25 multiple points can be gained in a single promotion period. The points can then be accumulated over six promotion periods up to a maximum of 7.5 multiple points. The maximum multiple points possible for the final multiple is 100. The addition of the HQP factor gives the examinee added incentive to keep trying for promotion in spite of repeated failure to gain a grade because of quota limitations.

<u>Factor</u>

Examination score
Performance factor
(Performance evaluation)
Length of service
Service in pay grade
Medals and awards
Passed but not advanced

All of the above information (except the examination score) is submitted to the Naval Education and Training Program Development Center with your examination answer sheet. After grading, the examination scores, for those passing, are added to the other factors to arrive at the final multiple. A precedence list, which is based on final multiples, is then prepared for each pay grade within each rating. Advancement authorizations are then issued, beginning at the top of the list, for the number of men needed to fill the existing vacancies.

SCOPE OF THIS TRAINING MANUAL

Before studying any book, it is a good idea to know the purpose and the scope of the book. Here are some things you should know about this training manual:

- It is designed to give you information on the occupational qualifications for advancement to MM1 and MMC.

- It must be satisfactorily completed before you can advance to MM1 or MMC, whether you are in the regular Navy or in the Naval Reserve.

- It is NOT designed to give you information on the military requirements for advancement to PO1 or CPO. Rate Training Manuals that are specially prepared to give information on the military requirements are discussed in the section of this chapter that deals with sources of information.

- It is NOT designed to give you information that is related primarily to the qualifications for advancement to MM3 and MM2. Such information is given in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

- The occupational Machinist's Mate qualifications that were used as a guide in the preparation of this training manual were those promulgated in the *Manual of Qualifications for Advancement*, NAVPERS 18068-C (with changes). Therefore, changes in the Machinist's Mate qualifications occurring after this change may not be reflected in the information given in this training manual. Since your major purpose in studying this training manual is to meet the qualifications for advancement to MM1 or MMC, it is important for you to obtain and study a set of the most recent Machinist's Mate qualifications.

- This training manual includes information that is related to both the KNOWLEDGE FACTORS and the PRACTICAL FACTORS of the qualifications for advancement to MM1 and MMC. However, no training manual can take the place of actual on-the-job experience for developing skill in the practical factors. The training manual can help you understand some of the whys and wherefores, but you must combine knowledge with practical experience before you can develop the required skills. The Record of Practical Factors, NAVEDTRA 1414/1, should be utilized in conjunction with this training manual whenever possible.

- This training manual deals almost entirely with the main propulsion plants and associated equipment installed on conventional steam-driven surface ships. It does NOT contain information that is primarily related to nuclear-powered ships, to diesel-driven ships, or to submarines.

- Chapters 2 through 16 of this training manual deal with the occupational subject matter of the Machinist's Mate rating. Before studying these chapters, study the table of contents and note the arrangement of information. Information can be organized and presented in many different ways. You will find it helpful to get an overall view of the organization of this training manual before you start to study it.

SOURCES OF INFORMATION

It is very important for you to have an extensive knowledge of the references to consult for detailed, authoritative, up-to-date information on all subjects related to the military requirements and to the occupational qualifications of the Machinist's Mate rating.

Some of the publications discussed here 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 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 entered.

NAVAL TRAINING (NAVEDTRA) PUBLICATIONS

The Naval Training Support Command and its field activities came directly under the command of the Chief of Naval Education and Training instead of the Chief of Naval Personnel. Training materials published by the Naval Education and Training Command are designated as NAVEDTRA in lieu of NAVTRA and NAVPERS; the numbers remain as originally assigned. The designators of publications printed hereafter will be changed as each publication is revised.

The Naval Training publications described here include some which are absolutely essential for anyone seeking advancement and some which, although not essential, are extremely helpful.

NAVEDTRA 10052.– *The Bibliography for Advancement Study, NAVEDTRA* 10052, is a very important publication for anyone preparing for advancement. This publication lists required and recommended Rate Training Manuals and other reference material to be used by personnel working for advancement. NAVEDTRA 10052 is revised and issued once a year by the Naval Education and Training Support Command. Each revised edition is identified by a letter following the NAVEDTRA number. When using this publication, be SURE you have the most recent edition.

The required and recommended references are listed by pay grade level in NAVEDTRA 10052. It is important to remember that you are responsible for all references at lower pay grade levels, as well as those listed for the pay grade level to which you are seeking advancement.

Rate Training Manuals that are marked with an asterisk (*) in NAVEDTRA 10052 are MANDATORY at the indicated pay grade levels. A mandatory training manual may be completed by (1) passing the appropriate Nonresident Career Course based on the mandatory training manual (2) passing locally prepared tests based on the information given in the mandatory training manual, or (3) in some cases, successfully completing an appropriate Navy school.

It is important to note that all references, whether mandatory or recommended, listed in NAVEDTRA 10052 may be used as source material for the written examinations, at the appropriate pay grade levels. In addition, references listed in this Rate Training Manual may also be used as source material for examination questions.

RATE TRAINING MANUALS.–Rate Training manuals are written for the specific purpose of helping personnel prepare for advancement. Some manuals are general in nature and are intended for use by more than one rating; others (such as this one) are specific to the particular rating.

Rate Training Manuals are revised from time to time to bring them up to date. The revision of the Rate Training Manual is identified by a letter following the NAVEDTRA number. You can tell whether a Rate Training Manual is the latest edition by checking the NAVEDTRA number and the letter following the number in the most recent edition of the *List of Training Manuals and Correspondence Courses*, NAVEDTRA 10061 (revised).

There are three Rate Training Manuals that are specially prepared to present information on the military requirements for advancement. These manuals are:

Basic Military Requirements, NAVEDTRA 10054 (current edition).

Military Requirements for Petty Officer 3 & 2, NAVEDTRA 10056 (current edition).

Military Requirements for Petty Officer 1 & C, NAVEDTRA 10057 (current edition).

Each of the military requirements manuals is mandatory at the indicated pay grade levels. In addition to giving information on the military requirements, these three books give a good deal of useful information on the enlisted rating structure; how to prepare for advancement; how to supervise, train, and lead other men; and how to meet your increasing responsibilities as you advance.

Some of the Rate Training Manuals that may be useful to you when you are preparing to meet the occupational qualifications for advancement to MM1 and MMC are discussed briefly in the following paragraphs. For a complete listing of Rate Training Manuals consult the *List of Training Manuals and Correspondence Courses*, NAVEDTRA 10061 (revised).

Tools and Their Uses, NAVEDTRA 10085-B. Although this training manual is not specifically required for advancement in the Machinist's Mate rating, you will find that it contains a good deal of useful information on the care and use of all types of handtools and portable power tools commonly used in the Navy.

Blueprint Reading and Sketching, NAVEDTRA 10077-C, contains information that may be of value to you as you prepare for advancement MM1 and MMC.

Mathematics, Vol. 1, NAVEDTRA 10069-C, and *Mathematics*, Vol. 2, NAVEDTRA 10071-B. These two training manuals may be helpful if you need to brush up on your mathematics. Volume 1, in particular, contains basic information that is needed for using formulas and for making simple computations. The information contained in volume 2 is more advanced than you will need for most purposes, but you may occasionally find it helpful.

Machinist's Mate 3 & 2, NAVEDTRA 10524-D. Satisfactory completion of this training manual is required for advancement to MM3 and MM2. If you have met this requirement by satisfactory completing an earlier edition of *Machinist's Mate 3 & 2*, you should thoroughly review the D revision of the training manual. Much of the information given in this edition of *Machinist's Mate 1 & C* is based on the assumption that you are familiar with the contents of *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

Rate Training Manuals prepared for other Group VII (Engineering and Hull) ratings are often a useful source of information. Reference to these training manuals will increase your knowledge of the duties and skills of other men in the engineering department. The training manual prepared for Boiler Technicians, Enginemen, and Boilermakers are likely to be of particular interest to you.

OFFICER TEXTS.—Officer texts that you may find helpful when you are preparing for advancement to MM1 and MMC include *Engineering Administration*, NAVEDTRA 10858-E; and *Principles of Naval Engineering*, NAVEDTRA 10788-B.

NONRESIDENT CAREER COURSES.—Most Rate Training Manuals and Officer Texts are used as the basis for nonresident career courses. Completion of a mandatory training manual can be accomplished by passing the nonresident career course that is based on the training manual. You will find it helpful to take other nonresident career courses, as well as those that are based on mandatory training manuals. Taking a nonresident career course helps you to master the information given in the training manual or text and also gives you a pretty good idea of how much you have learned from studying the book.

NAVSHIPS PUBLICATIONS

A number of publications issued by the Naval Sea Systems Command will be of interest to you. While you do not need to know everything that is given in the publications mentioned here, you should have a general idea of where to find information in NAVSHIPS publications.

The Naval Ships Technical Manual. is the basic doctrine publication of the Naval Sea Systems Command. Chapters in the manual are usually kept up to date by means of yearly revisions or less frequently for those chapters where yearly revisions are not necessary. Some chapters require intra-year changes; in these cases, either an intra-year edition or a NAVSHIPS Notice is distributed as a temporary supplement for use pending issue of the new edition of the chapter.

Chapters in *Naval Ships Technical Manual* of particular importance to Machinist Mate are referenced in this training manual. For a list of all chapters in the manual, see appendix A, chapter 9000.

The *Naval Ship Systems Command Technical News* is a monthly publication which contains interesting and useful information on all aspects of shipboard engineering. The magazine is particularly useful because it presents information which supplements and clarifies information contained in *Naval Ships Technical Manual* and because it presents information on new equipment policies and procedures.

The manufacturers' technical manuals that are furnished with most machinery units and many types of equipment are valuable sources of information on operation, maintenance, and repair.

OPNAVINST 4790.4

Job requirements at the E-6/E-7 levels dictate that you have a thorough knowledge of the 3-M System. OPNAVINST 4790.4, the *Maintenance and Material Management (3-M) Manual,* prescribes the policies for installation and operation of the system; the manual is the doctrine reference applying to the system and it takes precedence over other publications which may be in conflict with its contents. Information related to the system is also provided in the rate training manuals *Military Requirements for Petty Officer 3 & 2,* NAVEDTRA 10056-C, and *Military Requirements for Petty Officer 1 & C,* NAVEDTRA 10057-C, and the companion nonresident career courses. A review of the applicable portions of those publications may be beneficial before studying the remainder of this training manual.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. Films that may be of interest are listed in the *United States Navy Film Catalog,* NAVAIR 10-1-777. Copies may be ordered in accordance with the Navy Stock List of Forms and Publications, NAVSUP 2002. Monthly supplements to the Film Catalog are distributed to catalog holders.

When selecting a film, note its date of issue listed in the film catalog. As you know, procedures sometimes change rapidly. Thus, some films become obsolete rapidly. If a film is obsolete only in part, it may sometimes be shown effectively if before or during its showing you carefully point out to trainees the procedures that have changed. For this reason, if you plan to show a film to train other personnel, take a look at it in advance if possible so that you may spot material that may have become obsolete; verify current procedures by looking them up in the appropriate sources before the formal showing.

CHAPTER 2

TURBINES

Reliability is the paramount requirement of naval propulsion plant installations. If a ship is to be ready at all times for unlimited operations, the main units of the propulsion machinery, such as turbines, must constantly receive the best of care in operation, maintenance, and repairs.

This chapter presents selected information on operation, maintenance, and repairs of the most common types of main turbines. The MCC or MM1 should refer to the manufacturers' technical manuals and detail drawings in connection with inspection and repair of turbines. The manufacturers' recommendations regarding operation and methods of assembling and fitting parts should be followed whenever practicable. Periodic inspection and preventive maintenance should be in accordance with the Planned Maintenance System and applicable equipment technical manuals.

TYPES OF TURBINES

There are various types of turbines installed on naval ships; six major types are:

1. Type I (single-casing unit).—The Type I propulsion unit consists of one or more ahead elements, each contained in a separate casing and identified as a single-casing turbine. Each turbine delivers approximately equal power to a reduction gear.

2. Type II-A (straight-through unit).—The Type II-A propulsion unit is a two element straight-through unit, and consists of two ahead elements, known as a high pressure (HP) element and a low pressure (LP) element. The HP and LP elements are contained in a separate casing and are commonly known as the HP and LP turbines, respectively. The HP and LP turbines deliver power to a single shaft through a gear train and are coupled separately to the reduction gear. Steam is admitted to the HP turbine and flows straight through the turbine axially without bypassing any stages (there is partial bypassing of the first row of blades at high power), and then is exhausted to the LP turbine through a cross-over pipe.

3. Type II-B (EXTERNAL bypass unit.)—The Type II-B propulsion unit is similar to the Type II-A, except that provision is made for bypassing of steam around the first stage or first several stages of the HP turbine at powers above the most economical point of operation. Bypass valves are located in the HP turbine steam chest, with the nozzle control valves.

4. Type II-C (INTERNAL bypass unit).—The Type II-C is similar to the Type II-A, except that provision is made for bypassing steam from the first-stage shell around the next several (one or more) stages of the HP turbine at powers above the most economical point of operation. Bypass valves and steam connections are usually integral with the HP turbine casing; however, some installations have the valves separate, but bolted directly to the casing, with suitable connecting piping between the first-stage shell and valve to the bypass belt.

5. Type III (series-parallel unit).—The Type III propulsion unit consists of three ahead elements, known as the HP element, intermediate pressure (IP) element, and LP element. The HP and IP elements are combined in a single casing, and known as the HP-IP turbine. Steam is admitted to the HP-IP turbine and exhausted to the LP turbine through a crossover pipe. For

powers up to the most economical point of operation, only the HP element receives inlet steam, with the IP element being supplied in series with steam from the HP element exhaust. At powers above this point of operation, both elements receive inlet steam in a manner similar to that in a double-flow turbine. During ahead operation no ahead blading is bypassed. Series-parallel units are being used on some of the more recent naval combatant vessels, such as DEs, DDs and CVAs.

6. Type IV (cruising geared and vented unit).–The Type IV propulsion unit consists of a cruising element, HP element, and LP element–each contained in a separate casing. The cruising turbine is connected in tandem through a cruising reduction gear to the forward end of the HP turbine. The cruising turbine contributes power to the propeller shaft for powers up to the most economical point of operation, and for higher powers it is idled in a partial vacuum and supplied with cooling steam to prevent overheating. For cruising power, steam is admitted to the cruising turbine and then exhausted to the HP turbine inlet, and thence from the HP turbine exhaust into the LP turbine through a crossover pipe. The arrangement of the HP and LP turbine is identical to the Type II units. It is possible to disconnect the cruising turbine to allow for repair. Once disconnected, the HP turbine may be placed in service.

All of these six types of propelling units contain an astern element for backing or reversing. An astern element is located in each end of a double flow LP turbine casing or can be in either end of each single-casing turbine or single flow LP turbine.

Another classification which affects turbine life requirements and construction is:

Class A–Turbines for use in naval submarines.

Class B–Turbines for use in naval surface ships (warships, mine warfare ships and patrol ships).

Class C–Turbines for use in naval ships (amphibious warfare ships and auxiliary ships).

TURBINE OPERATION

When turbines are started from a cold condition, they are subject to expansive movements caused by the temperature of the incoming steam. Therefore, turbines should be warmed up carefully in order to obtain uniform heating of the turbine parts. During this warming period, the turbines should be monitored carefully for rubbing, for oil flow and bearing temperature, for proper gland-sealing steam pressure, and for freedom of operation.

The continued operating efficiency of steam turbines depends on maintenence of the relatively small radial clearances of gland and diaphragm packings. These clearances can be maintained at the approximate design values only by keeping the rotors straight. To obtain this condition, it is necessary to maintain a uniform temperature around the circumference of the rotor. If turbines are warmed up or cooled down with the rotors stationary, uneven heating will result. Such uneven heating will cause temporary bowing or distortion of the rotors and, to some extent, of the turbine casings. If a turbine is started during this period of distortion, rubbing and wear at the packings will take place, and under some conditions, if operation is permitted to continue, this bowing or bending of the rotor will be increased by the heat generated through rubbing contact. This will result in further wear of packings, with a consequent increase in packing clearances.

In order to minimize the amount of bowing of the rotors, they should be kept turning slowly during the warming or cooling of the turbines. One method of keeping the rotors turning is by use of the turning gear; another method is by steam spinning the rotors alternately ahead and astern at slow speeds. Usually a combination of both methods is used.

The length of time that the turbines should be kept turning after shutdown depends largely on local conditions. They should, however, be kept turning until the turbines cool off, or as long as there is a possibility that the plant will be called upon for a quick start.

LUBRICATION OF TURBINES

One of the more important factors in the operation and maintenance of main turbines is an adequate supply of lubricating oil having the correct physical and chemical qualities. The main lubricating oil system serves (1) to provide a continuous supply of oil to turbine and reduction gear bearings at the temperature for proper lubrication of the bearings; (2) and to remove heat.

Turbines are provided with one of the following: (a) NONADJUSTABLE ORIFICES in the oil supply lines to each journal bearing, (b) a NONADJUSTABLE ORIFICE in the inlet to or discharge from each thrust bearing, or (c) BEARINGS so constructed that the oil clearance around the journal acts as an orifice.

Under normal operating conditions, the temperature of the oil leaving the lube oil cooler should be between 120°F and 130°F. The outlet temperature of the bearing should be about 140°-160°F but not greater than 180°F. The maximum temperature rise allowable in the bearing (oil) is 50°F, even though such a rise may cause a final temperature of lower than 180°F.

Various means are provided for maintaining a continuous check on the supply of oil to the bearings, and on the bearing temperature as indicated by the temperature of oil flowing from the bearings. A thermometer is fitted in each bearing as near as possible to the point from which the oil drains from the bearing shell. On modern ships, four types of temperature indicators are in use for measuring journal bearings and thrust bearing temperatures: the mercury bulb thermometer, the bimetallic thermometer, the thermocouple, and the resistance thermometer element (RTE).

The bimetallic thermometer uses the principle of operation that two dissimilar metals expand differently or unequally when heated, and indicates the temperature on a calibrated gage. The bimetallic thermometer can be used to replace the mercury bulb thermometer for direct reading.

Thermocouples have been installed in some bearings to indicate the temperature of the babbitt material. The thermocouples are monitored automatically by an electrical scanning device or monitor, briefly described as follows: The thermocouples are connected to lamps and an alarm in the scanner through contacts. These contacts are made and broken by a rotary stepping switch pulsing circuit which provides the power pulses to operate the rotary stepping switch so that all thermocouple channels can be scanned within 10 seconds. Should the temperature on any bearing exceed 250°F, the lamp corresponding to the bearing will light and the alarm will sound. The alarm may be reset manually, but the light will remain on until the temperature returns to normal. Provision is also made for a meter in the scanner which can be connected to read the actual temperature on any one bearing at a given time.

It should be understood that there will ordinarily be some difference between the temperatures as indicated by the mercury bulb or bimetallic thermometers (where installed) and the scanner meter. These temperatures, however, are due primarily to the difference in position of the sensing elements for the bearing. If the temperature, as read by the thermometer or scanner, should suddenly rise without there having been a change in speed, there may be a distressed bearing, and the speed should be reduced, if possible, and the cause ascertained.

The RTE is an electrical resistance type thermometer installed within the bearing and used to measure the temperature of the babbitt material. The RTE uses the same type monitoring system as the thermocouple.

The bearings and gears of a modern warship require a high grade mineral oil (2190 TEP). The oil must be kept free from water and impurities by means of the purifier and the settling tank. In keeping a continous check on the condition of the lubricating oil, a routine procedure of taking oil samples should be followed. In addition, the oils should be tested at regular intervals whenever shore testing facilities are available, to determine the neutralization number, flash point, viscosity, and other physical or chemical properties which govern the effectiveness of oil as a lubricant. When operating the turbines, do not rotate the turbines with a lube oil temperature below 90° F except in an emergency. Operate the lube oil purifiers at least 12 hours per day when the ship is under way.

PROCEDURES FOR AN OVERHEATED BEARING

The rotor of every turbine must be supported in bearings, which serve the double purpose of carrying the weight of the rotor and maintaining the correct radial clearances between rotor and casing. All main turbines have a journal bearing at each end of the rotor, and a thrust bearing, to maintain correct axial clearances, usually at the forward end.

Bearing temperatures depend on the viscosity of the oil being used, the design of the bearing, the running speed, and the oil clearances. Watchstanders should be familiar with the normal operating temperatures of all bearings in their respective spaces. Watchstanders should also understand the precautions and procedures to prevent possible bearing troubles, and what procedures to follow when bearing troubles do occur.

Generally a bearing temperature rise above the maximum allowed may be traced to one of the following causes:

1. Malfunction of lubrication system; valves, piping, strainer or other components clogged or ruptured.
2. Babbitt metal wiped or excessively scored.
3. Insufficient cooling of oil by cooler.
4. Inadequate supply and/or improper quality of lubrication oil.
5. Bearing installed incorrectly causing uneven loading.
6. Bearing installed with less than design clearance.

Action to be Taken

1. Notify Main Engine Control and keep them informed.
2. Verify proper temperature of oil from discharge of cooler and provide an adequate supply to the bearings as indicated by pressure at most remote bearing and sight flow indicators.
3. Slow the engine if necessary to maintain bearing temperature within the maximum allowable limit.
4. Inspect lube oil strainers for presence of babbitt metal, or foreign matter.
5. Until a remedy is applied, the turbine must be slowed as necessary to avoid exceeding the safe bearing temperature. The turbine will be stopped only to prevent damage. Maintain lowered operation so that bearing temperatures will be lowered to safe limits before stopping, so as to prevent bearing(s) from seizing.
6. Main Engine Control must:
   a. Notify bridge of casualty action being taken, and an estimate of time required to correct the situation.
   b. Request permission to adjust speed as necessary.

Treatment of the Overheated Turbine Bearings

The following steps should be followed when turbine bearings become overheated:

1. Check the system and bearings to determine cause and then take necessary corrective action.
2. Renew or renovate lubrication oil prior to returning engine to service if system has been contaminated.
3. Main Engine Control must:
   a. Notify bridge of procedure required.
   b. Request permission to adjust speed as necessary.

ABNORMAL NOISE OR VIBRATION

Turbine rotors shall not be permitted to remain at rest for a period longer than five minutes while steam, including gland steam, is being admitted to the turbine. In ships having turning gear, this gear shall be rolling the turbine rotor before steam is admitted to the turbine glands. Turbines not provided with turning gear shall commence spinning operations as soon as gland steam is admitted to the turbine. Maintain a vacuum of about 25 inches of mercury by using the second-stage air ejector during warm-up. Higher vacuum during the warming-up period will retard heating and may cause distortion due to uneven temperatures.

If the rotor and casing are not evenly heated, unequal expansion, resulting in the distortion of the rotor or the casing or both, will take place. The results of this distortion are very noticeable in large turbine installations. Unless extreme care is taken to warm up the turbine properly, serious damage may be done.

If at any time while the turbine is in operation it suddenly begins to vibrate abnormally, the trouble may generally be traced to any one or a combination of the following troubles:

1. Water in the turbine.
2. Bearing failure.
3. Bent or broken propeller blades.
4. Unbalance due to broken or missing turbine blades.
5. Rubbing of blading labyrinth packing, or oil seal rings.
6. Bowed rotor.
7. Excessive differential expansion between rotor and casing.
8. Loss of flexibility in coupling between turbine and reduction gear.
9. Change in alignment of turbine to reduction gear.

If a rumbling sound is heard from the turbine when it begins to vibrate, the trouble is probably due to water or foreign matter in the turbine. Water in the turbine casing may be caused by either boiler priming or improper casing and steam line drainage. The turbine should be immediately slowed down until the abnormal vibration disappears. If, after slowing down, correcting boiler operation and checking casing and HP drains, the vibration still exists, the turbine shall be shut down and the interior of the turbine shall be inspected at the earliest opportunity.

When bearing troubles occur, the turbine should be stopped as soon as practicable to prevent damage to the turbine blading. The bearings should be inspected, and replaced or repaired as necessary. The cause of the trouble should be determined and appropriate steps should be taken to prevent similar troubles from recurring.

Rubbing of labyrinth or oil seal rings is usually caused by one of the following:

1. Excessive bearing wear.
2. Bowed rotor.
3. Improper installation of packing rings or oil seals.

Rubbing of shaft packing or oil seal rings will cause the shaft to overheat in the rubbing area, due to friction; and the shaft will start to show heating discoloration. An immediate inspection should be made to determine the cause of the trouble. If defective bearings are found, they should be replaced. A bowed rotor can be straightened by operating the turbine at low speeds. The shaft packing or oil seals may require refitting or renewal to give proper clearances.

When rubbing of turbine blading occurs, the cause will probably be a bowed rotor, a defective thrust bearing assembly, a wiped journal bearing, foreign material inside the casing, or differential expansion of turbine rotor and casing. When a rubbing noise in a turbine is heard, the turbine should be stopped immediately and the cause of trouble determined.

When warming up a turbine, or after a turbine has been warmed up, a vacuum shall not be maintained on the turbine unless the glands are properly sealed. Air leaking in along the shaft, particularly when standing still, tends to cause distortion of the shaft and rotor. If the rotor becomes distorted while standing by, close the drains to the condenser and bring the pressure of the gland steam to between 1/2 and 2 psi above atmospheric pressure, and spin the rotor alternately astern and ahead.

Foreign matter may enter a turbine casing through a defective steam strainer, or because of improper protection of a turbine that has been opened for inspection or repair. When any part of a turbine has been opened, the greatest care shall be exercised to prevent the entry of foreign matter. Inspection plates shall not be left off overnight, or for any length of time unless the openings are well covered. Before reassembling a turbine after it has been opened, a very careful examination shall be made of the rotor and interior of the casing for any articles left behind. An examination shall be made before the rotor is lowered in place, and another examination made before the casing cover is lowered in place.

Another cause of vibration is bent or broken propeller blades. Normally, this condition is first indicated by excess vibration of the main shaft and by a lesser vibration in the main reduction gears. When these conditions exist, the main turbines should be slowed until the noise and vibration stops or is within safe limits. An immediate inspection should be made to determine the cause of vibration.

If vibration of the turbine is caused by bent or broken turbine blading, the turbine should not be used until effective repairs can be made by experienced personnel.

ASTERN POWER LIMITATIONS

The MM1 and MMC must be familiar with astern power limitations for his ship. Each ship has its own designed operating requirements for maximum astern power. The turbine can be operated continuously at propeller speeds up to the maximum designed power. For detailed information on any given ship or unit, consult the manufacturer's technical manual or *NAVSHIPS Technical Manual.*

It is important that the main condenser vacuum be maintained at the best obtainable value during all astern operations to reduce astern windage heating in idle ahead elements. To reduce astern heating in idle ahead elements, keep astern exhaust temperature to a minimum. In order to do this, ships having superheat control shall enter and leave port with superheaters secured; only saturated steam should be used. Upon receipt of an astern bell, ships having superheat control must immediately commence lowering superheat at the rate of 10° F per minute. Watch ahead turbines closely for signs of overheating during prolonged astern operation. Overheating requires immediate slowing down.

ROTOR BALANCE

The turbine rotors are carefully balanced, both statically and dynamically. If, under any circumstances, a rotor becomes unbalanced, it will be necessary to have the rotor rebalanced.

Damage to the turbine rotor blading and balance weights will, understandably, cause unbalance of the rotor. Causes of turbine vibration should be thoroughly investigated before an attempt is made to balance the rotor. Balancing of the rotors should not be attempted by operating forces.

LEAKING NOZZLE CONTROL VALVES

On most modern naval ships, the amount of steam admitted to the turbine is controlled by a series of nozzle valves. The nozzle valves are controlled by a single handwheel and operated by individual cam or a lifting bar. The nozzle valves are opened in sequence. On older ships, the nozzle control valves are individually operated by hand and have two positions—fully open or fully closed. Variations in speed, with certain nozzle combinations, are controlled by a separate throttle valve controlling the steam pressure to the nozzles.

If not detected in time, leaking nozzle control valves for the main turbine will affect the propulsion operation by ahead elements overheating during astern operations. When the nozzles are leaking excessively, it is possible for the shaft to rotate in the ahead direction when the throttle valve is closed. This abnormal rotation can only be stopped by securing the guarding valve or by opening the astern throttle.

A test for leaking nozzle control valves can be made when the main plant is secured. The guarding valve and throttle valve (handwheel controlling the nozzle valves camshaft) are closed in a normal manner. Secure the turbine casing drain valves and the gland sealing valves. Next, remove the lagging pad and inspection cover from the high pressure turbine; with the inspection cover off, crack the guarding valve bypass valve. Then, make a visual inspection for steam leakage. There should be no steam being emitted from the turbine casing. If there is steam leakage, all valves and lines should be rechecked to make certain that the steam is coming from the nozzle valves and not from another source; the amount of steam being emitted from the inspection opening will indicate the condition of the nozzle control valves.

TURBINE MAINTENANCE

The maintenance of maximum operational reliability and efficiency of steam propulsion turbines requires a carefully planned and executed program of inspections and preventive maintenance in addition to strict adherence to prescribed operating instructions and safety precautions. If proper maintenance procedures are followed, abnormal conditions may be prevented.

Corrosion and rusting of the turbines may be almost entirely prevented by continuing the operation of the second-stage air ejector to dry the inside of the turbines after they have been shut down and while they are still hot.

The interior of main turbines should be inspected annually through available inspection openings. During this inspection, the effectiveness of the procedures in keeping the turbine dry and free from corrosion should be noted

The maintenance performed on the main engine turbines should be in accordance with the Planned Maintenance System and appropriate entries made in the Engineering Log.

MEASUREMENTS AND ADJUSTMENTS

The satisfactory operation of a turbine depends, along with other factors, on the maintenance of the proper running clearances, both radial and axial. The condition of the journal bearings affects the radial clearance, while the correct axial position of the rotor is controlled by the condition of the thrust bearing. Thrust bearing will assume a certain set when initially loaded, often referred to as BEDDING IN. In addition to this bedding-in, there is also a certain amount of deflection under load due to the elastic deformation of the parts.

It should be recognized that hot clearances recorded while underway by use of the rotor position indicator will include original oil clearances, bedding-in, and deformation, depending upon the load at the time of the reading. Due to these considerations, the running thrust clearance may be greater than the cold clearance.

Any large increase in the thrust clearance will permit the clearances between the rotating and stationary blading to decrease, and if permitted to continue, cause rubbing of the parts. When thrust clearances have increased to the maximum values shown in the equipment technical manual and the Planned Maintenance System, the thrust should be adjusted to bring it back to its original design clearance.

The clearances between the rotating and stationary blading of the high pressure and low pressure turbines may be checked by using the taper gages.

A suggested method of taking the thrust clearance is to move the rotor fore and aft, while ‑ng readings on a dial indicator, to show the total movement of the rotor. The thrust bearing must be completely assembled and the upper-half bearing cap bolted in place while readings are being taken. Attach a dial indicator to some fixed point, such as the bearing bracket, and arrange it in such a manner that the indicator spindle touches the shaft. Move the rotor as far as possible in one direction, make sure that the indicator spindle is just touching the shaft, and set the indicator dial at zero. Move the rotor fore and aft at least three times, using the average of the readings to determine the thrust clearance. Exert just enough pressure to hold the rotor firmly against the thrust shoes in each direction. Avoid bumping the rotor too hard, as this could cause false readings. Do not bar the rotor with the thrust shoes removed, as the packing teeth or blade shrouds may be damaged from bumping.

The axial position of a turbine rotor is maintained by means of a thrust bearing, usually of the pivoted segmental or Kingsbury type. With this type bearing, the axial position of the rotor is adjusted by machining from the filler piece, by adding shims, or by installing larger filler pieces. Consult the manufacturer's technical manual or *Naval Ships Systems Command Manual* for the specific installation.

Micrometer type depth gages are used for measuring bearing wear at each turbine journal bearing. Measurements may be taken without removing the bearing caps. Plugged openings are provided in the bearing caps for insertion of the depth micrometers.

When a turbine is first installed, take a reading at ach bearing with the depth micrometer; this reading should be logged for reference when taking future readings.

Readings should be taken when the units are cold and the rotors are stationary. It has been established that a bearing should be inspected when the depth gage shows the clearances have reached the maximum values of the technical equipment manual and the Planned Maintenance System. When the bearing is opened for inspection, the O.D. of the rotor journal and the I.D. of the bearing should be measured to determine actual clearance. Need for replacement of the bearing is to be based on these measurements and not the depth gage readings. For a detailed procedure on taking bearing measurements, refer to the appropriate section of *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

TURBINE BEARING MAINTENANCE

When a bearing is opened, it should be carefully inspected for ridges, scores, and amount of wear. It should be noted whether or not the babbitt lining has remained anchored to the shell. If the bearing is only slightly wiped, it can probably be scraped to a good bearing surface and restored to service. In this case, the clearance reading of the reconditioned bearing should be within tolerance on original design value.

Thrust Bearing Repairs

When trouble occurs or is suspected in a thrust bearing, the oil clearance in the bearing should be measured before the bearing is disassembled. If the readings are beyond allowable tolerances, the bearing should be disassembled for inspection.

When it is necessary to disassemble a thrust bearing, a careful inspection should be made of all parts. If there is slight rusting of the collar surfaces, the rust can be removed with fine crocus cloth to assure that metal is not removed from the collar. The work should be done slowly and carefully by experienced personnel. Renew the shoes if wear is evident and it exceeds allowable limits. When taking measurements of the shoes, consult the detail drawings for the place and design value of such a measurement.

Damaged thrust shoes which cannot be reconditioned by the ship's force are sent to a repair activity to be rebabbitted and machined. The radial edges of the shoes should be slightly rounded, otherwise the sharp edges will tend to scrape the oil film off the thrust collar.

If a thrust collar is found to be badly scored or if deep rust pits resulting in rapid wear (frequent replacement) of shoes, are present, the collar should be removed for repairs. On most turbines, the thrust collar can be removed without lifting the casing and without disturbing the lower half of the forward journal bearing. Removal and installation procedures are contained in the applicable technical equipment manual.

The propulsion turbine thrust collars on most designs are keyed to the shaft and held in place by a thrust nut threaded on the end of the shaft. To prevent the thrust nut from loosening and backing off, some designs have a lockwasher placed between the thrust nut and the keyed sleeve. The lockwasher ears must be bent squarely into the thrust nut notches to prevent the thrust nut from backing off. On modern installations, the collar is held in place by checknuts.

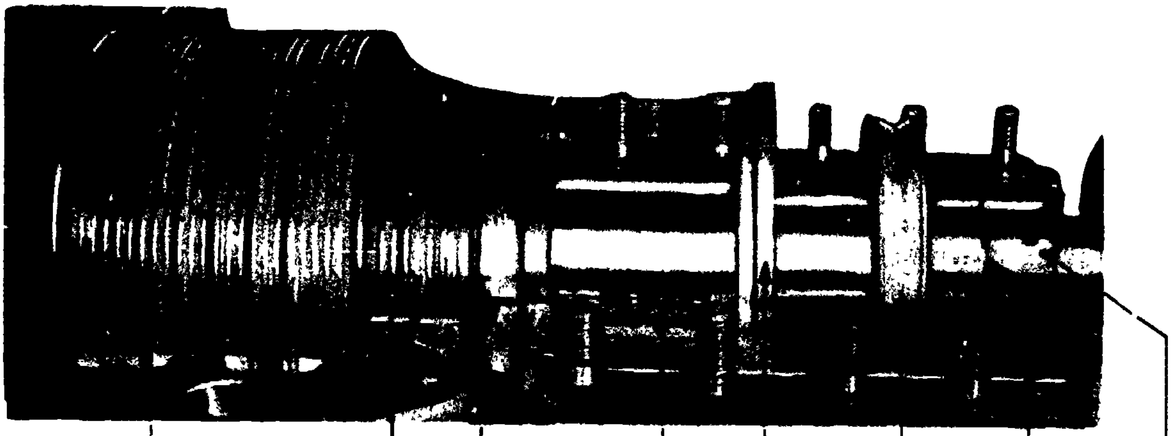
From a study of figure 2-1, it is apparent that the lower half of the inner casing will have to be removed before the thrust collar can be removed from the shaft. The lower inner casing, together with the thrust bearing, is shown in figure 2-2. The lower inner casing is removed from the outer thrust bearing housing by rotating it 180°, and lifting it from the journal. This is accomplished much the same as is removing the lower half of a journal bearing.

When a thrust collar is to be remachined, the bore should be square with the faces. The faces should be machined flat and smooth, and the thickness should meet the required specifications as stipulated on the blueprint or in the manufacturer's technical manual. The marks left by machining or grinding must be removed by lapping.

When the thrust bearing has been reassembled and the oil clearance taken, the thickness of the shim to be added should be computed. Take, for example, a thrust bearing that has the following clearances: designed clearance 0.010 inch; maximum clearance 0.020 inch; minimum clearance 0.007 inch. If a reading of 0.025 inch was obtained, a shim of 0.015 inch should be installed. Never may more than one shim be used to obtain the proper oil clearance.

Bearing Journal Repairs

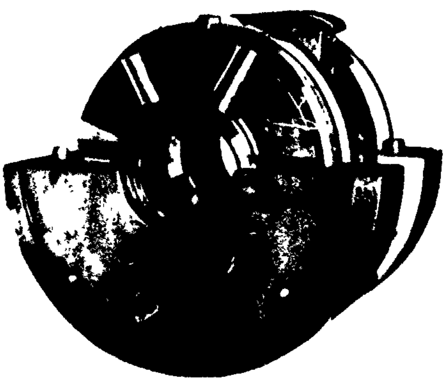
Bearing journals should be smooth, even, and free from rust at all times. With the increased emphasis on noise reduction in the Navy today, it is impossible to maintain, by hand methods of reconditioning, the roundness required for satisfactory operation. Any journal showing excessive damage that would be detrimental to bearings (i.e., is causing rapid wear and frequent replacement of bearings) should be sent to a repair activity for machining.



96.1
Figure 2-1.—Forward end of a high pressure turbine (base rings, leveling plates, and thrust shoes removed).

Fitting of Bearings

A bearing should have sufficient bearing area of fit in order to withstand maximum designed load.

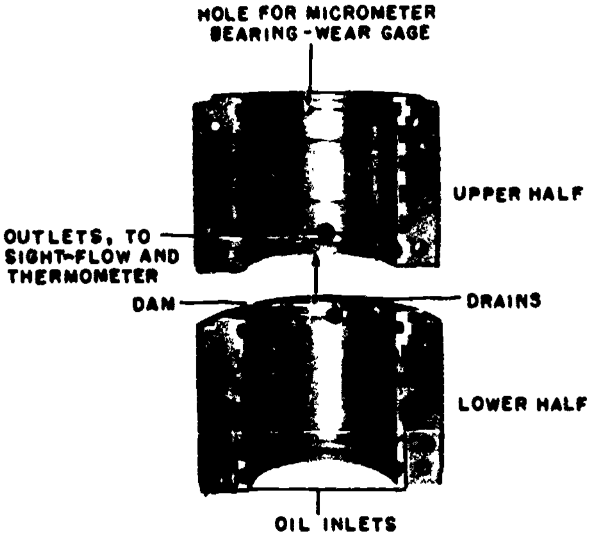


96.2
Figure 2-2.—Thrust bearing (assembled) and lower inner casing.

Modern bearings are usually finish bored to a diameter equal to that of the journal plus the desired oil clearance, and little or no fitting should be necessary. However, where hand fitting is required, a mandrel should be used; the mandrel should have a diameter equal to that of the journal plus the oil clearance. The first step hand fitting is to coat the mandrel with a compound such as Prussian blue. One half of the bearing is placed on the mandrel and turned slightly with a light pressure to cause the coloring on the mandrel to adhere to the high spots on the bearing. These high spots should be removed with a scraper and the fitting operation repeated until the coloring matter is uniformly distributed over the bearing surface, which indicates that all of the bearing surface is in contact with the journal. When bearing contact with the journal is checked, contact should be limited to a small arc, about 30° in the bottom of the bearing; however, there should be contact across the entire length of the bearing.

In scraping a bearing, care must be taken to see that the lining is kept concentric with the shell, and that taper runout is avoided.

REPLACEMENT OF JOURNAL BEARINGS.--When a bearing surface is found to be scored, uneven, considerably worn, wiped, or burned out, or if the metal is loose, the bearing must be rebabbitted or replaced. The detailed procedure for replacing turbine bearings will vary somewhat for different sizes and types of turbines. Where the upper and lower half of a bearing may be accidentally interchanged, or the axial position reversed, care must be taken to properly mark all parts, while the bearing is being disassembled. A bearing improperly installed, will not receive adequate lubrication. A typical turbine bearing is shown in figure 2-3.

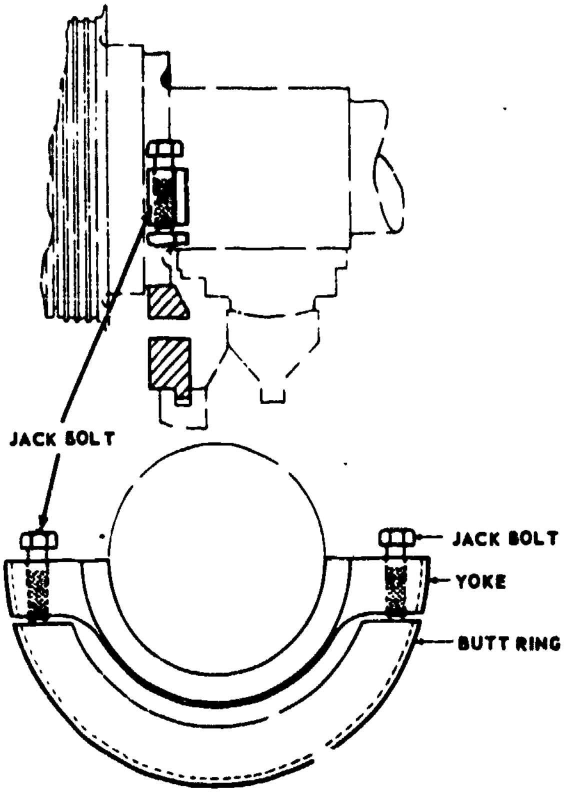


96.3

Figure 2-3.—A typical propulsion turbine journal bearing.

When a spare bearing is being readied for installation, it should be carefully cleaned and inspected. The two bearing halves should be bolted or clamped together and the inside diameter of the bearing measured with an inside micrometer. The inside diameter of the bearing should equal the outside diameter of the journal plus the designed oil clearance. The dimensions for a bearing may be found by checking the manufacturer's technical manual or the applicable blueprints. Ensure that a bearing that has been rebabbitted complies with dimensional specifications. Thermal distortion from heating and cooling the bearing shells during rebabbitting often results in dimensional variations of the spherical contour. The method of taking crown thickness readings is given in chapter 3 of *Machinist's Mate 3 and 2*, NAVEDTRA 10524-D.

After the bearing cap and the upper half of the bearing have been removed, the weight of the rotor is lifted by a jacking device (fig. 2-4). Lift the rotor vertically about .005", as determined by a dial indicator if available, to permit the lower half of the bearing to be rolled out. Lifting the rotor excessively will damage the shaft packing, and the bearing half might bind. Before removing the lower half bearing, ensure that the thermocouples are removed and RTE's are disconnected (if applicable). When the lower half of the spare bearing is installed, the jack is removed and the bearing reassembled. A depth gage reading is then taken to reestablish a constant.



96.4

Figure 2-4.—Special jack used for removing lower half of a journal bearing.

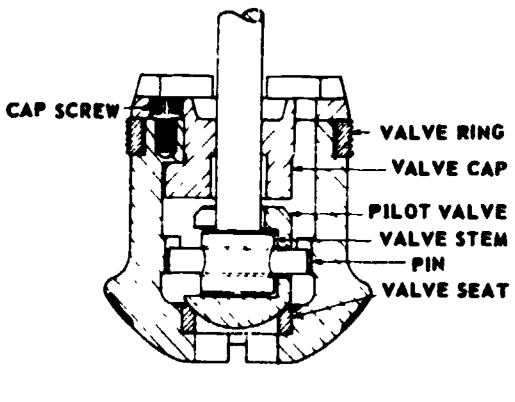
A bearing being used for the first time should be used at low speed; and the oil temperature should be checked at frequent intervals. A temperature rise of more than 1° F per minute usually indicates that the rubbing surfaces have been scored. An interval of 10 minutes is usually sufficient to determine the rate of temperature change. The technical equipment manual should always be followed to ensure correct reassembly and adjustment of the bearing.

When a defective bearing has been replaced by a spare, the old bearing should be rebabbitted as soon as possible if it is a reusable type. The usual procedure is to have a repair ship or shipyard rebabbitt and machine the bearing. The appropriate blueprints or manufacturer's technical manual will have to be furnished to the repair activity for the necessary detailed information concerning the bearing dimensions.

NOZZLE CONTROL VALVE REPAIRS

The nozzle control valves for the main high pressure turbine normally will operate for a long period of time without maintenance or repairs. However, the nozzle control valves are subjected to high steam pressures and temperatures, and in time they will require repairs. The MM1 and MMC should be familiar with the detailed construction of the nozzle control valves installed on his ship and the types of troubles that may occur.

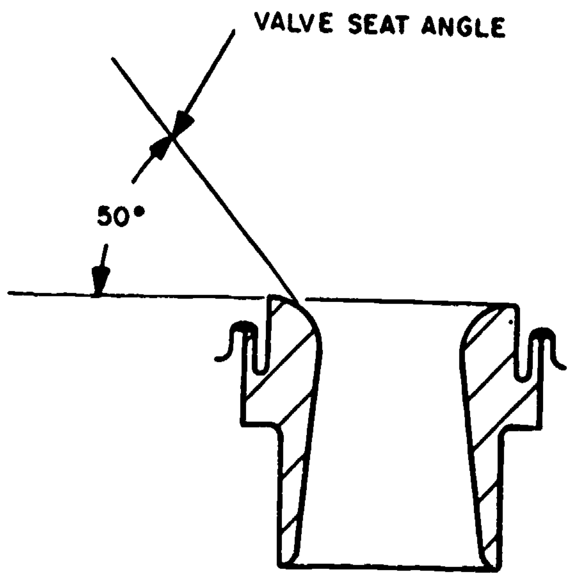
One of the more common troubles that may occur to nozzle control valves is the leakage of steam between the valve seat and disk. On some ships, the complete disassemble of the operating mechanism is not necessary. The steam chest cover is lifted and carefully placed on wooden blocks to prevent damage to the valves. This will permit inspection of valve disks and seats for damage. If leakage is suspected, the contact area of each valve with its seat should be checked by bluing the valve. If the valve does not make a good contact with its seat, do not use the valve to lap the seat as this makes a flat spot on both the valve and seat and destroys the spherical surface of the valve. Figure 2-5 shows an enlarged section of one type of nozzle control valve.



96.6

Figure 2-5.—Section of a nozzle control valve (pilot valve details).

Most valve seats have flat angular surfaces at the line of contact with the spherical surfaces of the valve disks. To resurface the valve seat, the following method is suggested: Turn a cast-iron cone with an angle the same as the valve seat angle, as shown in figure 2-6. Leave a tip on the upper end of the cone so that it can be held in and turned by hand, or driven by an air motor if considerable metal is to be removed. With this



96.43

Figure 2-6.—Valve seat angle.

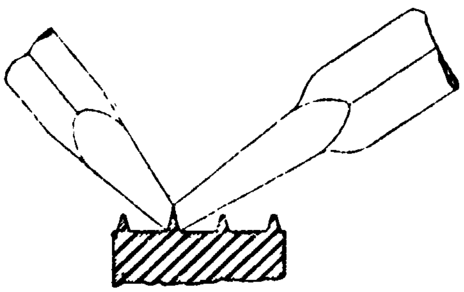
cone and some grinding compound, the flat angle of the valve seat may be resurfaced. A mechanical guide should be provided to keep the lap square with the seat and care should be taken not to grind off any more metal than is necessary. If the surface of the valve is not spherical because of pits or wear, place the valve in the lathe and polish it with emery cloth and oil until the surface is smooth and there is less than a 0.0005-inch runout. In this way the valve disk will maintain a spherical surface and seat tightly even if slightly out of line. Badly cut or damaged seats and disks are replaced rather than reconditioned.

RENEWAL OF SHAFT PACKING

Under normal conditions, if it becomes necessary to repair or replace the main engine shaft packing, the job will be done during a routine shipyard overhaul. When necessary, the outer rings of gland packing for most high pressure and low pressure turbines can be replaced by the ship's force, since this can be accomplished by removing the upper half of the packing casing. With a few exceptions, the inner gland packing rings cannot be replaced by ship's force, as it would require lifting the turbine casing. Most high pressure turbines in the Navy have only labyrinth packing. Some older designed high pressure turbines have carbon packing in the low pressure end only.

On some low pressure main turbines in which only labyrinth packing is used, usually the inner and outer gland packing is accessible when the upper half of the packing housing is removed.

Worn labyrinth packing should be replaced; however, if spare rings are not available, the packing may be repaired by using a chisel bar and a hand chisel as shown in figure 2-7. These tools are placed as indicated in the figure, the chisel is struck with a hammer, and then advanced around the periphery of the packing a trifle less than the tool's width. Care must be taken that each new position of the chisel overlaps the preceding position. This procedure expands the "tooth" in height and draws it out to its original featheredge. The drawing out of the "teeth" must be continued to give the packing clearance specified on manufacturer's drawings or in manufacturer's technical manuals.



96.7

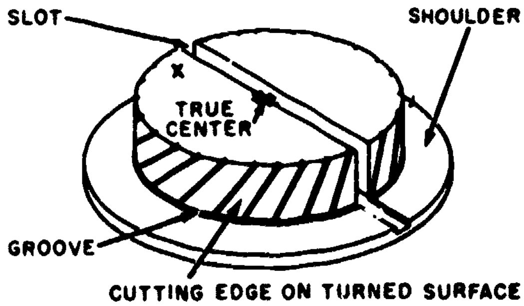
Figure 2-7.—Restoring height of labyrinth packing "lands."

If the clearance is not available from plans or instructions, the drawing of "teeth" should be continued until they come within 0.005 inch of touching the shaft.

When it becomes necessary for the ship's force to overhaul carbon packing, it is recommended that the removed segments be placed in a box in such a manner that adjacent segments of a ring will be next to each other. Each segment of carbon packing is marked on each end with the number of the ring of which it is a part. As each segment is removed, an examination should be made for scores, grooves, and general condition. The rings can be refitted or renewed, whichever is necessary.

The retainer springs must be carefully inspected and tested. If they are weak or corroded, they must be renewed.

Refitting or renewing carbon packing rings is a rather a difficult and tedious job. You can simplify the work considerably by making up a jig or mandrel, similar to the one shown in figure 2-8, and a checking gage. The jig can be made



47.25

Figure 2-8.—Jig for fitting carbon packing rings.

from a square steel plate or from round bar stock; it should be approximately 3/8 inch thicker than the ring to be fitted, and about 1 1/2 inches greater in diameter (or perimeter, if you are using a square plate) than the inside diameter of the ring. The upper part should be turned down to a diameter which is about 0.001 or 0.002 inch LESS than the final bore required for the carbon ring, and a cutting edge should be raised around the periphery of the turned surface. The cutting edge is made by making diagonal cuts about 0.003 inch deep, with a pitch of about 1/2 inch, on the turned surface. The final diameter of the turned surface, including this raised cutting edge, should be the same as the required inside diameter of the carbon ring.

The width of the turned surface should be about 1/8 inch greater than the width of the carbon ring to be fitted. A small groove should be cut in the shoulder as an extension of the turned surface; this groove will provide a space in which loose carbon particles can collect, so that they will not interfere with the fitting of the carbon ring.

Cut a 5/16-inch slot through the turned surface, and continue it about 1/8 inch into the shoulder or flange below the turned surface. One edge of the slot must pass EXACTLY through the center, forming a true diameter of the circular face of the jig; the other edge of the slot will therefore be slightly off-center. Be sure to mark that part of the face which forms a true half-circle after the slot has been cut. Remove all sharp edged from the turned surface of the jig and make sure that the edges of the slot are smooth.

The checking gage can be made by turning a piece of steel to the same diameter as the shaft to which the carbon ring is to be fitted. The checking gage should be 1/8 inch thicker than the width of the ring.

Assemble the segments of the carbon ring on the checking gage, and hold them in place with the garter spring. Check the fit of the joints and the clearance between the ring and the gage. If the joints do not fit properly, or if the bore is too large, remove the ring from the checking gage. Place each segment separately on the jig and smooth the ends with find sandpaper wrapped around a flat file or a block. Each segment must be placed on the true half of the jig, and the true centerline must be used as a guide when removing carbon from the end of the segment. Remove carbon from the ends of each segment until the assembled ring is TOO SMALL to fit over the checking gage. Then assemble the entire ring, with its garter spring, on the fitting jig. Hold the ring against the bottom of the jig and turn it by hand until the cutting edge on the jig has removed enough carbon to allow the ends of the segments to make proper butt joints.

Remove the carbon ring from the jig and try it on the checking gage. If the ring is too small, put it back on the jig and remove some more carbon from the inner surface of the ring. If the ring is too large, replace each segment on the jig and remove carbon from each end until the ring is the correct size.

When carbon rings are fitted in the manner just described, the ends of the segments will make firm butt joints and there will be a small clearance between the inner surface of the ring and the shaft. On some auxiliary turbines, the carbon rings are designed to rub against the shaft and have a clearance between the butting ends of the segments. When fitting these rings, make the jig with a diameter which is, including the raised cutting edge, the same as the diameter of the shaft. Rings cut on this jig should make contact with the shaft along the full length of each segment, and the ends of the segments should be filed down to make the proper butt clearance.

LIFTING THE TURBINE CASING AND ROTOR

Although shipyard personnel are responsible for lifting turbine casings and rotors, the MM1 and MMC should have a good understanding of the procedures involved. Before a turbine casing is lifted, preliminary work has to be done. All the turbine lifting gear, special tools, and equipment should be inventoried and inspected at least one day before the actual work is to begin. The manufacturer's technical manuals and Coordinated Shipboard Allowance List (COSAL) can be used for inventory of the lifting gear. Ship's force should be ready (if necessary) to furnish turbine lifting gear which includes: casing guides, casing supports, rotor guides, rotor supports, lifting brackets, and other items that the ship will have aboard. On some ships the turbine lifting gear has been removed, and therefore will be available only in naval shipyards and on tenders and repair ships. The ship's blueprints will have listed on them all of the lifting gear placed aboard the ship.

The decision as to when casings should be lifted will be made by the type commander. This decision will be based upon the past performances of the particular type of turbine, data furnished by the CO of the ship, and recommendations made by the forces afloat. In an emergency, turbine casings may be lifted before permission is granted, but a detailed report must be promptly submitted to NAVSEA.

Regulations for Lifting Turbines

Three months prior to each regular overhaul, a report by the CO of the ship on the condition of each propulsion turbine shall be submitted to the type commander. *NAVSHIPS Technical Manual,* chapter 9411, should be consulted for the information required to be contained in the report.

Any answer from NAVSEA involving a recommendation to disassemble the casing or to perform additional tests or inspections will be directed to the type commander with copies to the reporting ship, the planned overhaul activity, Ships Parts Control Center (SPCC), and any other activities concerned. Final authority for disassembling the casing is the responsibility of the activity (usually the type commander) controlling the operating schedule and overhaul funds of the ship.

Lifting Casing and Rotor

Whenever turbine casings are lifted for any purpose, advantage should be taken of the opportunity to observe the condition of all nozzles, blading, packing rings, and other internal parts. When practicable, such examinations should be made when adequate facilities are available for necessary repairs which are beyond the capacity of the ship's force.

All turbine measurements and clearances should be taken before and after repairs; a permanent record of these measurements should be maintained. (Fig. 2-9 shows the method of checking the rotor position with a taper gage.) The record must also include the material condition revealed when the turbine is opened and after repairs are made. A report of the above facts must be forwarded to the Naval Sea Systems Command, with copies to the ship concerned and to her home yard.

Before the casing can be lifted, the preliminary work can be started. The covers over the flexible couplings, between the turbines and the reduction gears, must be removed. If a cruising turbine rotor is to be lifted, the cruising turbine reduction gear also must be disassembled, as the pinion is part of the turbine shaft. Sections of the main steam lines are disconnected and removed. If an HP or LP turbine

98.8

Figure 2-9.—Using a taper gage to check the position of a rotor.

casing is to be lifted, the crossover line between these turbines must be removed. Drain lines and gland seal lines may be removed if necessary. In some turbine installations, obstructions to lifting, such as steam lines and ventilation ducts, may have to be removed, and it may be necessary to remove some of the insulation from the turbine.

Proper temporary stowage of the piping, valves, nuts, bolts, tools and other necessary materials must be provided, either in or out of the engineroom. Passageways and working areas must be kept free of tools and materials being used. Avoid damage to the piping, gages, gage lines, lagging, and other material.

After the preliminary work has been completed, the turbine casing horizontal joint bolts are removed. As a rule, the vertical joint bolts on the high pressure turbine are not removed, except where repairs require the joint to be opened. Most inspection covers have caution plates which call attention to internal bolts or fittings which must be removed. The upper housings and upper halves of main turbine bearings must be removed. When disassembling turbine casing bolts that were tightened by heat, it is important that heat be applied when loosening these bolts. After all the bolts have been removed, the joint can be broken loose by means of jack bolts, if necessary.

When the ship is built, padeyes are welded in the overhead of the engineroom for attaching chain falls for lifting heavy objects. The manufacturer's technical manual and the ship's blueprints will give detailed information on the arrangement, number and size of the chain falls, wire slings, and shackles to be used to lift any particular piece of machinery. The lifting arrangement for a turbine casing will allow the four corners of the upper casing to be lifted in a plane parallel to the flange of the lower casing. Four upper casing guide pins are installed. If there is a scale on the guide pin, this scale should face outboard where it can be readily seen. The location of the upper casing guide pins is shown in figure 2-10. The guide pins are used to prevent any damage to the turbine blading and shaft packing. As the turbine casing is raised or lowered, it should be handled in a manner to prevent tilting or swaying so as not to strike the turbine blading or shaft packing.

When the turbine casing is ready to be lifted, men are assigned to the various jobs and stations. It usually requires 10 or 12 men to raise or lower a main turbine casing. (Four men operate the chain falls. Four men, one at each corner of the turbine casing, take measurement readings from the guide pins. Usually an observer is stationed at each side of the turbine, and one man will supervise the entire operation.)

The casing is slowly raised, keeping uniform heights at the graduated guide pins to ensure that the casing is level and not tilted. The usual procedure is to slowly raise the casing about one inch at a time until the upper casing is clear of the rotor. As a safety precaution, blocks are inserted under the upper casing flange as the casing is raised. When the casing is clear of the rotor, it can be either swung clear of the turbine, or secured in a position above it as shown in figure 2-11.

After the casing has been raised to the desired height (not higher than the guide pins), and if it is not to be swung clear, the four upper casing supports are installed, as shown in figure 2-11. Applicable blueprints should be on hand to show the exact location for installing the various turbine supports and guide pieces. The upper casing support pieces are bolted to the upper and lower casing flanges. Figure 2-11 shows a turbine opened for inspection.

A similar procedure is used for lifting a turbine rotor as is used in lifting the upper casing. Four rotor guides are attached to the lower casing of the turbine, as shown in figure 2-12. There are different methods of attaching the wire slings to the turbine rotor. One method, shown in figure 2-12, is used for a small turbine rotor. Another method uses a special lifting yoke and a lifting plate to raise the rotor. The lifting yoke, a form of clamp, is attached to the forward end of the rotor. The lifting plate, a padeye welded to a plate, is attached to the after face of the shaft coupling flange. Shackles are attached to lifting devices so that chain hoists may be used in lifting the rotor.

The rotor guide pieces perform two functions: when the rotor is being raised, the guide pieces keep it in a vertical plane passing through the centerline of the rotor shaft; machined surfaces on the inside corners of the rotor guide pieces prevent the rotor from moving forward or aft. The machined surfaces bear with a small clearance against shoulders of the forward and after ends of the shaft. In many cases, special bushings are attached to the rotor shaft. These bushings are located on the sections of the shaft between the pairs of rotor guide pieces.

After all preliminary work has been completed, the turbine rotor is slowly lifted from the lower casing. The rotor is lifted approximately one inch at a time and measurements taken at each end to ensure that both ends have been raised evenly. Adjustments in height are made as necessary. This procedure is repeated until the rotor has cleared the lower casing. A rotor that has been lifted clear of the casing is shown in figure 2-12.

96.44

Figure 2-10.—Lifting or lowering upper casing of a high pressure turbine.

When a turbine rotor is to be placed in its raised position, special securing devices such as rotor guide saddles, rotor supporting bars, rotor guide tie brackets, and rotor guide spacer bolts are used. These attachments are secured in place so as to properly support the weight of the rotor. The same procedures are used to lift and support the high pressure and the low pressure turbine rotors.

CHECKING ROTOR BALANCE

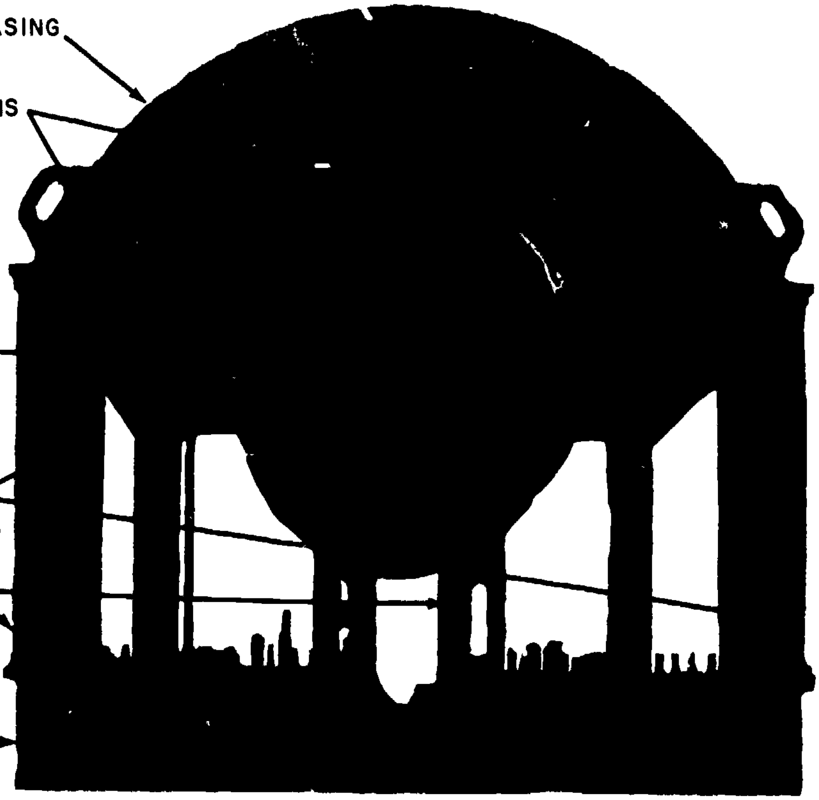
If turbine rotor unbalance is suspected, the rotor should be checked for balance while still in the casing. The normal procedure is to notify the type commander who will determine the repair activity which will conduct the necessary tests and inspections. All turbine rotors must be rebalanced when any of their blading has been renewed or their balance has been altered by repairs.

MAJOR OVERHAUL CHECKPOINTS

When a turbine casing has been lifted for repair, there are several tests and inspections required by the Naval Sea Systems Command. A complete turbine repair guide list can be found in chapter 9411 of *NAVSHIPS Technical Manual.* Some of the important points (a through g, fig. 2-13) to be checked are as follows:

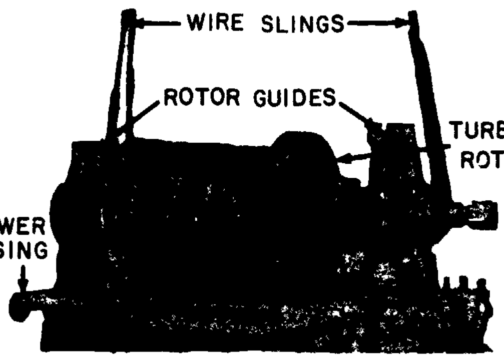
1. High pressure buckets (a).—Scale may be found here. It may usually be removed by washing with water; however, several other methods are employed for hard-to-remove deposits. It is not recommended to use chemical solvents in removing scale.

2. Low pressure buckets (b).—Steam entering the low pressure turbine, having lost heat in the high pressure turbine, may contain water. The water may cut the bucket tips, especially near the entrance edge. If the bucket tips are



96.45

Figure 2-11.—Upper casing and rotor resting on supports.



96.11

Figure 2-12.—Lifting a high pressure rotor.

deeply eroded, it may be necessary to renew the buckets. If the buckets are not replaced, the amount of erosion can be measured by using a feeler gage and a straightedge.

3. Water drainage orifices (c).—If the blading has eroded, the drain orifices will probably be plugged. The orificies should always be cleaned out so that normal drainage can take place.

4. Diaphragm joints (d).—Flow marks will be evident if there is leakage across the diaphram joints. This leakage indicates that the joint is not properly seated. To correct severe leakage, clad welding and remachining the joint faces may be necessary.

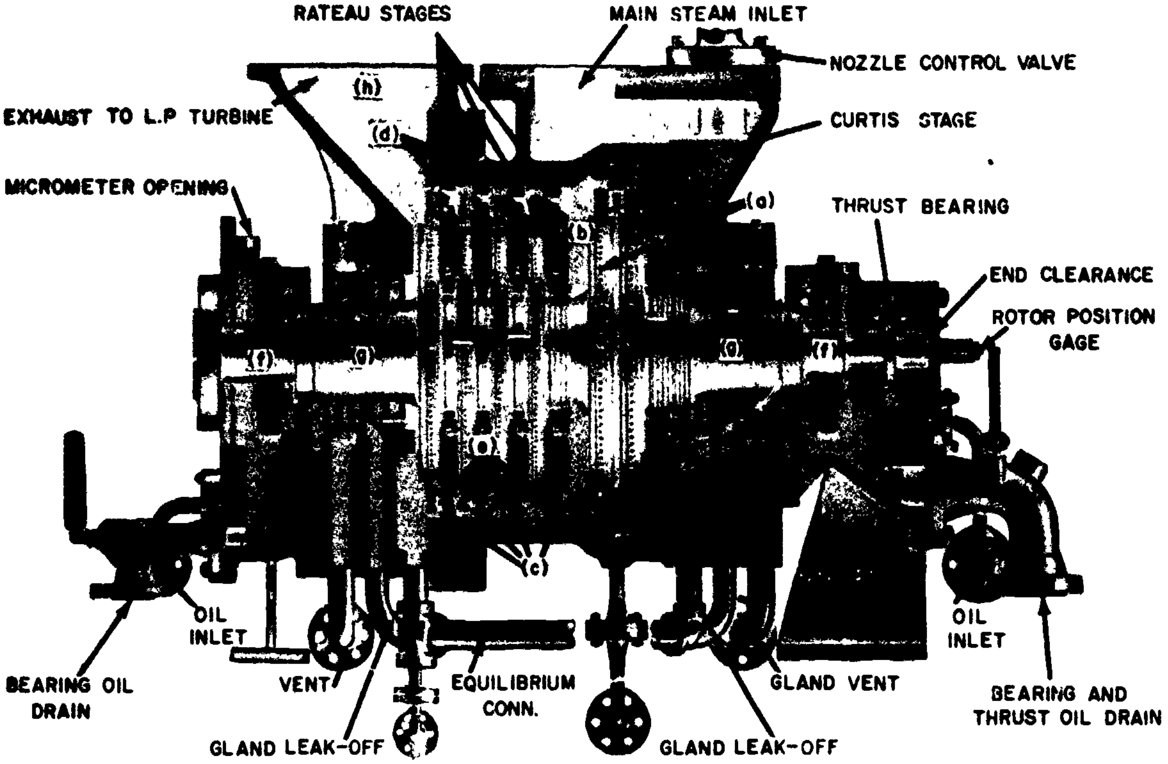
5. Rotor axial clearance (e).—The rotor axial clearance should be measured and compared with the designed clearance. If adjustments are necessary, the axial clearance can be adjusted by installing a filler piece of the proper thickness in the thrust bearing.

6. Journal bearing clearances (f).—If journal bearing clearances are beyond allowable limits, the bearings must be rebabbitted or replaced.

7. Shaft packing rings (g).–If the clearance of the shaft packing is beyond the manufacturer's specified tolerance, the packing rings should be renewed or reconditioned.

8. Casing interiors.–If erosion or cracks are found here, it may be necessary to make repairs to the parts. Any repair welding requires specific NAVSEA approval.

for any articles left behind. This examination should be made before the rotor is lowered into place and again before the upper casing is lowered and secured in place. This examination should be made by a responsible officer of the ship. If the work is being done by a naval repair activity, a responsible officer from the repair activity will also make an inspection. An entry,



47.4

Figure 2-13.–Required overhaul checks.

REASSEMBLING A TURBINE

When a turbine is opened for a major overhaul, the repair guide list in *NAVSHIPS Technical Manual*, the type commander's instructions, the manufacturer's technical manual and the instructions issued by the Shipyard Commander should be checked–and followed where applicable–before the turbine is reassembled.

Before reassembly of a turbine that has been opened, a very careful examination should be made of the rotor and the interior of the casing including the names of both officers, is to be made in the Engineering Log.

Sealing Turbine Flange Joints

Before the upper half of the turbine casing is lowered into place, the horizontal joints should be cleaned with a solvent. If the solvent fails to clean the flange, mechanical cleaning methods may be necessary. DO NOT use belt sanders, files, etc. Use only mild scraping or a crocus cloth.

30

Apply a thin film of Prussian blue to the joint on the upper half casing and to the horizontal ioint of internal stationary parts assembled in the upper half casing. Carefully reassemble the upper half casing on the lower half. Install all joint studs: lubricate threads and faces of nuts and all washers, and assemble nuts. Cold tighten all studs to approximately one-half the normal operating stud stress in order to obtain a proper joint check. Disassemble joint nuts and studs and carefully raise the upper half casing and observe the blue contact on the joint of the lower half casing.

If the blue check indicates a poor contact due to local high areas, these areas should be either scraped or stoned so as to obtain a proper blue check in this area by using a large surface plate (minimum 12 X 18 inches). In some cases, the joint may contain eroded areas and grooves caused by steam leakage. To seal these areas and grooves and prevent subsequent leakage, it may be necessary to apply a small amount of weld. The welding should be done under the supervision of a capable welding enginee, and in accordance with approved procedures in *NAVSHIPS Technical Manual*

When the joints on both the upper and lower halves of the casing show at least a continuous (approximately 85 percent) contact on the surface between the bore of the turbine casings and the bolt holes with 1/2 inch continuous band inside, bolt holes, and pumping groove. Also, an intermittent (approximately 50 percent) contact on the surface between the bolt holes and the outer edge of the casing flanges, the joints should be cleaned of all foreign material and the upper half casing lowered into position for assembling.

The entire joint surface on each casing shall be lightly coated with a thin even film of one of the joint compounds permitted by *NAVSHIPS Technical Manual* The use of sheet packing for flange joints is prohibited.

The main horizontal and vertical joints in some turbine casings have a system of grooves in the joint faces for pressure pumping with sealing compound during emergency repairs. These grooves shall not be filled with sealing compound during routine overhaul.

Tightening Turbine Flange Joints

With high steam pressures and temperatures it is difficult to make the turbine casing joints (when cold) sufficiently tight by using extension wrenches. Bolts are given an additional stress by tightening after heating. The heating is usually done with an acetylene torch or with electric heating elements: because acetylene torches are available on most ships, they are more commonly used. Almost all horizontal joint bolts of cruising and high pressure turbines are drilled their full length for the application of heat. In applying the heat, a standard acetylene torch is fitted with an attachment which is provided with a 1/16-inch orifice. For complete details on applying the heat and tightening the bolts, refer to the manufacturer's technical manual and *NAVSHIPS Technical Manual*. The above procedures on making up and tightening turbine flange joints also apply for steam chest cover joints.

DOCK TRIALS

When a main propulsion turbine has been opened for inspection and repair, the work is not considered complete until a DOCK TRIAL and a POST REPAIR TRIAL have been satisfactorily completed and any deficiencies found have been corrected.

The engineer officer of each ship may issue instructions for operating the plant during a dock or post repair trial; however, the general procedure will be as follows:

Before oil is circulated through the lube oil system, muslin bags are fitted in the lube oil strainers. The muslin bags, available at naval shipyards, will prevent very fine particles of dirt from entering the bearings and gears. A lube oil pump is started and oil is circulated through the system. The muslin bags must be changed often (the interval of time between changes is usually set by the engineer officer). When dirt or other foreign matter is no longer found in the muslin bags, the turning gear should then be engaged. Personnel will be stationed at various points around the turbine to listen for unusual noises. If no abnormal conditions are detected, the turbine can be considered ready for a dock trial.

During a dock trial, the ship will remain tied to a pier and the engines turned by steam. The commanding officer usually determines the maximum number of rpm the engines will be permitted to turn. On a ship having two engines, one engine should turn in the ahead direction and the other engine must turn in the astern direction; then the engines should be reversed.

The main plants are warmed up in accordance with the engineer officer's instructions. When the engines are ready to be tested, the special sea detail should be stationed. The officer of the deck will shift his watch from the quarter deck to the bridge and personnel will be stationed around the turbines to detect unusual noises or other abnormalities. When all stations are manned and the engineering plant is ready, the engineer officer will request permission from the bridge to test main engines. When the OOD is certain that the area around the fantail is clear of boats, mooring lines, etc., he will grant permission to test main engines. When the main engines have been tested and found satisfactory, the engineer officer will report to the bridge that the main engines are ready for dock trial. One main engine will then be designated to go in the ahead direction and the other main engine will be designated to go in the astern direction. The appropriate orders will be rung up on the engine order telegraph and the required rpm will be indicated on the engine order telegraph. When these orders are received in the engineroom, the engine itself will be turned, by steam, at the indicated rpm. If no abnormal conditions are found, the engineer officer will request an increase in speed. The OOD will order the rpm increased (about 5 rpm each change) until the maximum allowable rpm is reached. If no abnormal conditions are detected, the main engines may be considered ready for a post repair trial.

Information on Post Repair Trials is given in a later chapter of this training manual.

SAFETY PRECAUTIONS FOR TURBINES

Turbine installations in the Navy vary to such an extent that detailed safety precautions for each type cannot be covered in this training manual. The following general safety precautions are prescribed by NAVSEA and should be observed:

1. Do not admit steam to operate the turbine until the exhaust system has been prepared to receive turbine exhaust and the entire system has been properly drained. Damage can be caused by carryover of slugs of water in the steam system when starting up turbines. This cannot be over-emphasized; make sure all portions of the system including the piping are properly drained.
2. Do not use auxiliary exhaust steam for warming up the turbines.
3. Be sure that the lubrication system is operating properly before turning over the main engines.
4. Keep the rotors turning over continuously while the main engines are being warmed up.
5. Never fail to investigate any unusual noise coming from a turbine.
6. Do not put way on the ship when turning over the main engines during warmup.
7. If a turbine vibrates, slow it down, investigate and locate the cause.
8. Except in an emergency, do not admit steam to the astern turbine until steam to the ahead turbine is secured, and vice versa.
9. Before getting under way, be sure that all steam lines are drained properly.
10. When steam pressure drops, do not open the throttle to such an extent that the operating pressure of the steam drops to a dangerously low point.
11. Stop the engines immediately if the oil supply fails.
12. If the throttle valve sticks, close the guarding valve or bulkhead stop as soon as possible. In an emergency, the guarding valve can be used as a throttle.
13. Excerise care to prevent the entry of foreign matter into a turbine when it is opened for inspection.
14. When turbine is thoroughly cooled, close turbine drains.
15. Do not lash overspeed trip or a speed-limiting governor, or take other steps to render them inoperative.

16. Before starting turbine, inspect externally to see that it is clear of foreign matter, especially if the unit has not been operated for a long period.

17. Before turbine is put in service, test the overspeed trip, if provided.

18. Avoid air being drawn through turbine glands with the rotor at rest.

CHAPTER 3

REDUCTION GEARS

This chapter contains information on the operation, care, and maintenance of reduction gears found on Navy ships. The MM1 and MMC must be familiar with the design and construction details of naval reduction gears. To acquire this information a review of chapter 4 of *Machinist's Mate 3 and 2*, NAVEDTRA 10524-D, plus information contained in chapter 9420 of *NAVSHIPS Technical Manual* will be useful. For details of any particular reduction gear installation, a thorough study of the manufacturer's technical manual will be necessary.

MAIN REDUCTION GEARS

The main reduction gear is one of the largest and most expensive units of machinery found in the engineering department. Main reduction gears that are installed properly and operated properly will give years of satisfactory service. However a serious casualty to main reduction gears, will either put the ship out of commission or force it to operate at reduced speed. Extensive repairs to the main reduction gear can be very expensive because they usually have to be made at a shipyard.

OPERATION OF MAIN REDUCTION GEARS

Some things are essential for the proper operation of reduction gears. Proper lubrication includes supplying the required amount of oil to the gears and bearings, plus keeping the oil clean and at the proper temperature. Locking and unlocking the shaft must be done in accordance with the manufacturer's instructions. Abnormal noises and vibrations must be investigated and corrective action taken. Gears must be inspected in accordance with the current instructions issued by NAVSEA, the type commander, or other proper authority.

Proper Lubrication of Gears and Bearings

Proper lubrication of reduction gears and bearings is of the utmost importance. The correct quantity and quality of lubricating oil must, at all times, be available in the main sump. The oil must be CLEAN; and it must be supplied to the gears and bearings at the pressure and temperature specified by the manufacturer.

In order to accomplish proper lubrication of gears and bearings, several conditions must be met. The lube oil service pump must deliver the proper discharge pressure. All relief valves in the lube oil system must be set to function at their designed pressure. The quantity of oil to each bearing is controlled by an orifice in the supply line. The orifice opening must be in accordance with the manufacturer's instructions or the supply of oil will be affected. Too small a quantity of oil will cause the bearing to run hot. If too much oil is delivered to the bearing, the excessive pressure may cause the oil to leak at the oil seal rings. Too much oil may also cause a bearing to overheat.

Lube oil must reach the bearing at the proper temperature. If the oil is too cold, one of the effects is insufficient oil flow for cooling purposes. If the oil supply is too hot, some lubricating capacity is lost.

For most main reduction gears, the normal temperature of oil leaving the lube oil cooler should be between 120°F and 130°F. For full power operation, the temperature of the oil leaving the bearings should be between 140°F and 160°F. The maximum TEMPERATURE RISE of oil passing through any gear or bearing, under any operating conditions, should not exceed 50°F, and the final temperature of the oil leaving the gear or bearing should not exceed 180°F. This temperature rise and limitation may be determined by installed thermometers or resistance temperature elements.

Cleanliness of lubricating oil cannot be overstressed. Oil must be free from impurities, such as water grit, metal, and dirt. Particular care must be taken to clean out metal flakes and dirt when new gears are wearing in or when gears have been opened for inspection. Lint or dirt, if left in the system may clog the oil spray nozzles. The spray nozzles must be kept open at all times. Spray nozzles must never be altered without the authorization of the Naval Sea Systems Command.

The lube oil strainers cannot trap particles of metal and dirt which are fine enough to pass through the mesh. These fine particles can become embedded in the bearing metal and cause wear on the bearings and journals. These fine abrasive particles passing through the gear teeth act like a lapping compound and remove metal from the teeth.

MAIN SUMP OIL LEVEL.—Lubricating oil is supplied to the gears from the main engine lubrication system, with a connection to each bearing and with nozzles located so that a constant spray of oil is directed to the gears. This constant spray of oil over the gears lubricates and cools the gears. For reduction gears, where the maximum oil level in the sump may reach the bottom of the bull gear, positive means are taken to ensure that the bull gear does not dip into the oil. An oil excluding pan is fitted around the bottom of the bull gear to prevent oil from reaching it, during normal operation.

If the gear is allowed to dip into the oil, the churning action of the gear will foam. Under normal conditions, only a small quantity of oil comes in contact with the bull gear, therefore no dangerous vibration and no churning effect will occur. Oil from the gears is swept out of the pan the bull gear and drained into the sump. A drain hole is provided on the bottom of the pan so located that drainage of any accumulated water is assured when the ship is on an even keel. When there is too much oil in the sump, the gear will churn and aerate the oil. Because the aerated oil is a poor lubricant, there will be an increase in temperature. If this occurs, the engines must be slowed or stopped until the excess oil can be removed and normal conditions restored. Routine checks should be made to see that the lubricating oil is maintained at the proper level. Any sudden loss or gain in the amount of oil, in the main sump, should be immediately investigated.

EFFECTS OF ACID AND WATER IN OIL.—Water and acid in oil are extremely dangerous. The oil must be tested frequently for water and at regular periods for acid. Even a small amount of water in oil can cause pitting and rusting. Fresh water can accumulate, due to leaking turbine packing glands or from condensation. Where main sump tanks are located at the skin of the ship, salt water may leak into the lube oil. Salt water may also enter through leaks in the lube oil cooler. When salt water is found in a lube oil system, corrective steps must be taken. The source of the salt water must be found and sealed off. The contaminated oil must be removed from the system by adequate flushing with clean oil.

When oil is contaminated with fresh water adequate purification will prevent an accumulation of water in the oil but the source of water must be found and eliminated. Under normal operating conditions, operating the lube oil purifier 12 hours a day, while underway, will be sufficient; however, if the presence of fresh water is noted, the purifier will have to be operated until there is no visual indication of water in the oil and no water is discharged from the purifier. If, with additional purifier operating time, the oil does not clear up, the purifier should be checked for improper operation. The presence of salt water or fresh water in lube oil should never be ignored. The system should be checked immediately and the source of contamination should be eliminated.

When the main engines are secured, a lube oil pump should be kept running and the jacking gear should be kept engaged and kept turning until the engines have reached approximately room temperature (ambient). While oil is circulating, the lube oil cooler should be left in use and the purifier should be operated. Circulating oil will carry away the heat from the engines which might otherwise reach the bearings. Turning the engines will prevent the rotors from becoming bowed. Operating the purifier will eliminate water caused by condensation on the interior of the reduction gear casing.

Ships should take advantage of every opportunity to have laboratory tests made of the lube oil. Good engineering practice dictates that this be accomplished every three months or more frequently if unusual conditions prevail. Samples should be tested for water, acid, and sediment content. When the neutralization number exceeds 0.50, the lube oil should be replaced.

All petroleum products deteriorate (oxidize) in the presence of air and heat. The products of oxidation include organic acids which, if present in sufficient concentration, have deleterious effects on (1) alloy bearings at elevated temperatures, (2) galvanized surfaces, and (3) the demulsibility of the oil with respect to fresh and salt water.

OIL EMULSION.–With continuous use, the lube oil will increase in acidity, and the free fatty acids will form mineral soaps which can form a stable oil and water emulsion. Once the emulsion has formed, the removal of water becomes more difficult, and of more importance, the oil loses its lubricating quality. The formation of an oil film becomes impossible and the oil must be renovated. Operating with emulsified oil will result in wiped bearings and worn gear teeth.

Locking And Unlocking The Main Shaft

In an emergency, or in the event of a casualty to the main propulsion machinery of a turbine-driven ship, it may be necessary to stop and lock a propeller shaft to prevent damage to the machinery. When the shaft is stopped, engaging the turning gear and then applying the brake is the most expeditious means of locking a propeller shaft while under way.

LOCKING THE MAIN SHAFT.–By carrying out actual drills, engineroom personnel should be trained to safely lock and unlock the main shaft. Each steaming watch should have sufficient trained personnel available to stop and lock the main shaft. NAVSEA requires the following procedure:

1. Reduce ship's speed to approximately one-half full power speed or less, or the maximum designated locking speed.
2. Close the ahead throttle and open the astern throttle until the shaft is stopped.
3. Throttleman is to take note of astern steam pressure required to stop shaft.
4. Engage the turning gear and immediately lock the turning gear motor shaft brake.
5. Close the astern valve slowly.
6. Throttleman in the unaffected engineroom is to maintain required revolutions as directed by Main Engine Control.
7. DO NOT SECURE lubricating oil to an engine whose shaft is locked while the ship is underway.

CAUTION: During drills the shaft should not be locked more than five minutes, if possible. The ahead throttle should NEVER be opened when the turning gear is engaged. The torque produced by the ahead engines is in the same direction as the torque of the locked shaft; to open the ahead throttle would result in damage to the turning gear.

The maximum safe operating speed of a ship with a locked shaft can be found in the manufacturer's technical manual. Additional information on the safe maximum speed that your ship can steam with a locked shaft can be found in *NAVSHIPS Technical Manual*, chapter 9420.

UNLOCKING THE MAIN SHAFT.–The recommended procedure for unlocking the main shaft is as follows:

1. Reduce the temperature of the main steam as much as practicable by cutting out the superheat burners.
2. Bring the ship to the same speed at which the turning gear was engaged. Open the astern

throttle to the same pressure as used in the locking process.

3. Immediately disengage the turning gear, slowly close the astern throttle, then release the lock on it. It may be necessary to adjust the astern throttle pressure slightly in order to disengage the turning gear.

4. When turning gear is disengaged, slowly close the astern throttle.

5. Open ahead throttle slowly and continue underway.

CAUTION: If the shaft has been locked for five minutes or more, the turbine rotors may have become bowed, and special precautions are recommended. Before the shaft is allowed to turn, men should be stationed at the turbines to check for unusual noises and vibration. When the turning gear is disengaged, the astern throttle should be slowly closed, the torque produced by the propeller passing through the water will start the shaft rotating. If, when the propeller starts to turn, vibration indicates a bowed rotor, the ship's speed should be reduced to the point where little or no vibration of the turbine is noticeable and this speed should be maintained until the rotor is straightened. If operation at such a slow speed is not practicable, the turbines should be slowed by use of the astern throttle, to the point of least vibration but the turbines still operating in the ahead direction. When the turbines are slowed to the point of little or no vibration, the shaft should be operated at that speed and the ahead throttle should be opened slightly to permit some steam flow through the affected turbine. The heat from the steam will warm the rotor and aid in straightening it. Lowering the main condenser vacuum will add additional heat to the turbines; this will increase the exhaust pressure and temperature.

As the vibration decreases, the astern throttle can be closed gradually, allowing the speed of the shaft to increase. The shaft speed should be increased slowly and a check for vibration should be maintained. The turbine is not ready for normal operation until vibration has disappeared at all possible speeds.

Noises and Vibration

On steam-turbine driven ships, noises may occur at low speeds or when maneuvering, or when passing through shallow water. Generally, these noises do not result from any defect in the propulsion machinery and will not occur during normal operation. A rumbling sound which occurs at low shaft rpm is generally due to the low pressure turbine gearing floating through its backlash. The rumbling and thumping noises which may occur during maneuvering or during operation in shallow water, are caused by vibrations initiated by the propeller. These noises referred to are characteristic only of some ships and should be regarded as normal sounds for these units. These sounds will disappear with a change of propeller rpm or when the other causes mentioned are no longer present. These noises can usually be noticed in destroyers when the ship is backing, especially in choppy seas or in ground swells.

UNUSUAL NOISES.–A properly operating reduction gear has a definite sound which an experienced watchstander can easily learn to recognize. At different speeds and under various operating conditions, the operator should be familiar with the normal operating sound of the reduction gears on his ship.

If any abnormal sounds occur, an investigation should be made immediately. In making an investigation, much will depend on how the operator interprets the sound or noise.

The lube oil temperature and pressure may or may not help an operator determine the reasons for the abnormal sounds. A badly wiped bearing may be indicated by a rapid rise in oil temperature for the individual bearing. A certain sound or noise may indicate misalignment or improper meshing of the gears. If unusual sounds are caused by misalignment of gears or foreign matter passing through the gear teeth, the shaft should be stopped and a thorough investigation should be made before the gears are operated again.

For a wiped bearing, or any other bearing casualty that has caused a very high temperature, this procedure should be followed: If the temperature of the lube oil leaving any bearing has exceeded the permissible limits, slow or stop the unit and inspect the bearing for wear. The bearing may be wiped only a small amount and the shaft may be operated at a reduced speed until the tactical situation allows sufficient time to inspect the bearing.

VIBRATION.–The most common causes of vibration in a main reduction gear installation are: faulty alignment, bent shafting, damaged propellers, and improper balance.

A gradual increase in the vibration in a main reduction gear that has been operating satisfactorily for a long period of time can usually be traced to a cause outside of the reduction gears. The turbine rotors, rather than the gears, are more likely to be out of balance.

When reduction gears are built, the gears are carefully balanced (both statically and dynamically). A small amount of unbalance in the gears will cause unusual noise, vibration, and abnormal wear of bearings.

When the ship has been damaged, vibration of the main reduction gear installation may result from misalignment of the turbine, the main shafting, the main shaft bearings, or the main reduction gear foundation. When vibration occurs within the main reduction gears, damage to the propeller should be one of the first things to be considered. The vulnerable position of the propellers makes them more liable to damage than other parts of the plant. Bent or broken propeller blades will transmit vibration to the main reduction gears. Propellers can also become fouled with line or cable which will cause the gears to vibrate. No reduction gear vibration is too trivial to overlook. A complete investigation should be made, preferably by a shipyard.

MAINTENANCE OF MAIN REDUCTION GEARS

Under normal conditions, major repairs and major items of maintenance on main reduction gears should be accomplished by a shipyard. When a ship is deployed overseas and at other times when shipyard facilities are not available, emergency repairs should be accomplished, if possible, by a repair ship or an advanced base. Inspections, checks, and minor repairs should be accomplished by ship's force.

Bearing Maintenance

Under normal conditions, the main reduction gear bearings and gears will operate for an indefinite period. If abnormal conditions occur, the shipyard will normally perform the repairs. Spares are carried aboard sufficient to replace 50 percent of the number of bearings installed in the main reduction gear. Usually each bearing is interchangeable for the starboard or port installation. The manufacturer's technical manual must be checked to determine interchangeability of gear bearings.

Special tools and equipment needed to lift main reduction gear covers, to handle the quill shaft when removing bearings from it, and to take required readings and measurements, are normally carried aboard. The special tools and equipment should always be aboard in case emergency repairs have to be made by repair ships or bases not required to carry these items.

The manufacturer's technical manual is the best source of information concerning repairs and maintenance of any speeific reduction gear installation.

JOURNAL BEARINGS.–Each babbitted bearing shell of the reduction gear may be considered as having a pressure bearing half and a nonpressure bearing half. The nonpressure bearing half has a radial scribe line at one end of the geometric center. The pressure bearing half has three radial scribe lines at one end; the central scribe being at the geometric center and the additional scribes located on either side of the central scribe at an angle of 45°. These scribes are placed by the manufacturer. The crown thickness of each shell, at these scribe points, is measured with a micrometer, usually 1 1/4 inches from the end of the shell. Such measurements are taken during the initial alignment by the manufacturer, and are stenciled adjacent to each scribe line to be used as constants for future alignment checks. In this way the amount of wear can always be determined whether the wear is against the upper or lower half of the shell.

On older ships not equipped for checking alignment by the crown-thickness and proof-staff method, the gear is first checked for alignment by measuring the percentage of tooth contact in accordance with *NAVSHIPS Technical Manual*, chapter 9420.

After alignment is established, bearings are removed and marked and the crown thickness of the bearing measured and stenciled adjacent to each scribe line. Bearing wear is measured subsequently by using the crown-thickness method based on the constants as stenciled.

The amount of bearing clearance allowed should not be great enough to allow incorrect gear tooth contact. The designed bearing clearances are given in the manufacturer's technical manual. These clearances are also given in the blueprints for the main reduction gears. The maximum allowable clearance can be determined by referring to *NAVSHIPS Technical Manual*, chapter 9420.

Replacing bearings in the main reduction gear is a major undertaking. When a casualty (such as the loss of lube oil) occurs, the high speed pinion shaft bearings are more likely to be wiped than the other main gear bearings. These high speed pinion shafts, which are coupled to the high pressure and low pressure turbines, will have a higher rotary speed than other shafts in the reduction gear. If the bearings are inspected, the high speed pinion bearings should be checked first. If these bearings are not wiped, it is safe to assume that the bearings which rotate at lower speeds are not wiped. If repairs are to be made, the first step would be to study the manufacturer's technical manual and the blueprints for the reduction gear. The MM1 or MMC should be able to decide whether the repair work should be attempted and should have a clear understanding of the construction details and repair procedures before starting a repair job. Other factors to be considered are: location of the ship, available repair facilities, available repair parts, and the operating schedule of the ship.

In making repairs, the first step is to engage the turning gear and set the brake to ensure that the shaft will not turn while repairs are being made. All oil must be pumped out of the main sump tank. A clean settling or storage tank can be used to store the oil until it is ready for use again. Then a section of the reduction gear cover is lifted by using chain-falls and wire slings. When the gear cover is moved out of the way, the bearing cover can be removed. Next the bearing must be turned so that the bearing split is on the horizontal plane and the top half of the bearing can be lifted off. The gear shaft must be supported when the bottom half of the bearing is removed. A dummy bearing is rolled in while the lower half is rolled out. The dummy bearing supports the weight of the shaft and keeps the shaft in position. Special precautions should be taken to prevent the shaft from being turned or lifted so that the gear teeth do NOT become unmeshed. If the gear teeth become unmeshed and are not matched marked, it is necessary to follow a complicated and detailed procedure to reassemble and time the gears. The setting up of the locked train gear system is done at the factory and at shipyards.

If the bearing has excessive clearance, is badly wiped, or heavily scored, examine other representative bearings to determine the extent of the damage. Replace all bearings on that particular shaft to maintain correct gear alignment.

To replace a bearing, proceed as follows:

1. Review the maintenance history of the reduction gears to determine if special bearings are necessary.

2. Measure the diameter of the journal (with a micrometer) and compare the present readings with the original readings, as recorded.

3. Check the crown thicknesses of installed and replacement bearings and compare readings. If scraping is required for the replacement bearing, use a full-sized mandrel and prussian blue to check the work. Shaft parallelism must be maintained.

4. To maintain shaft parallelism, bearings on the ends of gear or pinion shafts shall not differ more than 0.002 inch.

5. When a spare bearing is installed or a damaged bearing is scraped to maintain correct tooth contact, the crown thickness shall be stamped on the bearing shell.

6. Dowels are used, between the bearing halves, to locate the bearings in the upper casing. Upper and lower bearing halves must be mated parts. Interchanging of upper and lower bearing halves is prohibited.

7. Examine the condition of the journal whenever bearings are removed. If the surface of the journal is slightly scored, it must be stoned very lightly and polished. Only experienced personnel should stone a journal. Always oil a journal before rolling in a new bearing.

NOTE: If journals are badly scored, they may be ground undersize or restored to design diameter—by chrome plating. If a journal is ground undersize, it might be necessary to provide undersize bearings. This should be accomplished only by a shipyard and in accordance with existing NAVSEA instructions. The new journal diameters and bearing clearances must be recorded.

When installing a spare bearing, make sure that it is well oiled, then roll the lower half into position, removing the dummy bearing. The upper half can be placed in position, and then the complete bearing can be shifted to its proper position. Ensure that the dowels are in place and that the bearing assembly is in its required position, in accordance with the manufacturer's instructions. The bearing cap can be lowered into position and securely bolted down.

Before the gear cover is lowered into position, a careful inspection should be made to see that the inside of the gear installation is free of all dirt, tools, rags, and other foreign matter that would be harmful to the gears. After the gear cover is lowered into position and bolted down, the lube oil can be pumped to the sump. Before the oil is circulated through the system, MUSLIN bags should be placed in oil strainers. The muslin bags will trap any dirt or foreign matter that is too fine to be stopped by the strainer. A lube oil service pump should be started to circulate oil through the system. The muslin bags should be changed at 30-minute intervals until they no longer pick up dirt. The turning gear can then be engaged and started.

THRUST BEARINGS.--This chapter contains only general information on different methods of taking end play readings on the main thrust bearing. See the manufacturer's technical manual for specific information on any given unit.

Checking the end play for any six- or eight-shoe thrust bearing must always be done with the top half of the bearing bolted down solidly; otherwise the base rings will tilt because of the freedom of movement given the leveling plates, and a false reading will be obtained.

A record of the main thrust readings must be kept and referred to when checking the main thrust bearing. Over a period of years, the normal wear of a pivoted-shoe thrust bearing is negligible. However, when the bearing is new, there may be a slight settling of the leveling plates. Any increase in the end play of a main thrust bearing indicates that the surfaces of the thrust shoes should be inspected, and necessary repairs made.

In some main thrust bearings, a port is provided (in the main thrust bearing cap over the thrust shoes) for inspection purposes. This port has a removable cover of sufficient size to permit the withdrawal of thrust shoes that are in line with it.

Checking Thrust While Under Way.--The simplest means of checking end play is to use a dial indicator on any accessible flange on the main shaft while the engines are going slowly ahead and then astern. This can usually be done when the ship is maneuvering to approach a pier or an anchorage. The speeds should be slow enough to avoid adding deflections of bearings parts and housing to the actual end play. But, the speed should be sufficient to ensure that the full end play is actually taken up.

Some ships have the main thrust bearing located at the forward end of the main reduction gear, and constructed as a component part of the gear. A spring-loaded pin gage (located in the bearing end cover housing) and a micrometer depth gage are used to measure the end play. The pin gage cover is removed and the anvil of the depth gage is placed on the machined surface of the pin gage housing. The micrometer is carefully turned so that the spindle pushes the installed pin against the main shaft. All slack must be taken up; but excessive force must not be used, as it will lift the micrometer anvil from the machined surface.

Another reading is taken with the main shaft operating in the opposite direction. The difference between the two readings is the end play. It is always good practice to take more than one set of readings to ensure that the total end play was taken up and that the readings are accurate.

Jacking on a Shaft Flange.--If it is not practicable to measure the end play while running, the next choice is to jack the shaft (while it is still warm) fore and aft at some convenient main shaft flange. A dial indicator is mounted on a rigid support, convenient to some main shaft flange and the shaft is jacked forward and then astern. Make certain that the shaft movement is free—but do not use too great a force; excessive force might cause deflections of metal parts to be added to the actual end play. The main difficulty in using the jacking method is finding suitable supports where no structural damage will be done.

Gear Teeth

The importance of proper gear tooth contact cannot be overemphasized. Any abnormal condition which may be revealed by operational sounds or by inspections should be corrected as soon as possible. Any abnormal condition which is not corrected will cause excessive wear which may result in general disintegration of the tooth surfaces.

If proper tooth contact is obtained when the gears are installed, little wear of teeth will occur. Excessive wear cannot take place without metallic contact. Proper clearances and adequate lubrication will prevent most gear tooth trouble.

WEAR-IN OF GEAR TEETH.—Gears which have been realigned and new gears should be given a wearing-in period at low power before being subjected to the maximum tooth pressure at full power.

TOOTH CONTACT.—For proper operation of the gears, it is essential that the total tooth pressure be uniformly distributed over the total area of the tooth faces. This uniform pressure is accomplished by accurate alignment and adherence to the designed clearance.

The designed center-to-center distance of the axes of the rotating elements should be maintained as accurately as practicable but the axes of pinions and gear shafts must always be parallel. If the shafts are not parallel, the load is concentrated on one end of a helix; the result may be flaking, galling, pitting, featheredges on teeth, deformation of tooth contour, or breakage of tooth ends.

CHECKING TOOTH CONTACT.—The length of tooth contact across the face of the pinion is a means of determining if reduction gear alignment is satisfactory. One method used to static check the length of tooth contact is to apply a thin coat of prussian blue to a band of teeth on one element and coat a similar band on the mating element with red lead. The coatings must be thin and even. Rotate the two bands into contact by jacking back and forth 3 or 4 times.

Either copper sulphate or blue or red Dykem is used to determine tooth contact for operating conditions. Dykem should be used for dock trials as it will show markings for light load conditions. Copper sulphate markings will remain visible after longer and high power operations than will Dykem markings. Lubricating oil must be removed from the gear teeth by a cleaning agent, before the compound is applied; after the tooth contact is determined, the compound must be removed from the gear teeth to prevent possible contamination of the lubricating oil. The gear teeth should then be oiled.

Remember that some gear teeth are cut with a very slight taper to offset the effects of torsional twist and bending. In such gearing, full contact across the teeth will not be obtained.

TOOTH CONTOUR.—The designed tooth contour must be maintained. A lack of this tooth contour can cause load concentrations with consequent scoring.

TOOTH SURFACE WEAR.—If proper contact is obtained when the gears are installed, the initial wearing, which takes place under conditions of normal load and adequate lubrication, will smooth out rough and uneven places on the gear teeth. This initial wearing-in is referred to as NORMAL WEAR or RUNNING IN. As long as operating conditions remain normal, no further wear will occur.

Small shallow pits starting near the pitch line, will frequently form during the initial stage of operation; this process is called INITIAL PITTING. Often the pits (about the size of a pinhead or even smaller) can be seen only under a magnifying glass. These pits are not detrimental and usually disappear in the course of normal wear.

Pitting which is progressive and continues at an increasing rate is known as DESTRUCTIVE PITTING. The pits are fairly large and are relatively deep. Destructive pitting is not likely to occur under proper operating conditions, but could be caused by excessive loading, too soft material, or improper lubrication. It is usually found that this type of pitting is due to misalignment or to improper lubrication.

The condition in which groups of scratches appear on the teeth (from the bottom to the top of the tooth) is termed abrasion, or scratching. It may be caused by inadequate lubrication, or by the presence of foreign matter in the lubricating oil. When abrasion or scratching is noted, the lubricating system and the gear spray fixtures should immediately be examined. If it is found that dirty oil is responsible, the system must be thoroughly cleaned and the whole charge of oil centrifuged.

The term "scoring" denotes a general roughening of the whole tooth surface. Scoring marks are deeper and more pronounced than scratching and they cover an area of the tooth, instead of occurring haphazardly, as in scratching or abrasion. Small areas of scoring may occur in the same position on all teeth. Scoring, with proper alignment and operation, usually results from inadequate lubrication, and is intensified by the use of dirty oil. If these conditions are not corrected, continued operation will result in a general disintegration of the tooth surfaces.

SPOTTING GEAR TEETH.–Any abnormal conditions which may be revealed by operational sounds or by inspections should be corrected with the least possible delay. Rough gear teeth should be stoned smooth if it is certain that the roughening was caused by the passage of some foreign matter. Any tooth deterioration which cannot be traced to a casualty should be investigated, giving special attention to the condition of the bearing, to lubrication, and to the possibility of a change in the supporting structure, which has disturbed the parallelism of the rotors.

To spot-in surfaces of reduction gear teeth, the pinion teeth are coated lightly with prussian blue. Then the gear is turned in its ahead direction by using the jacking gear. As the gear teeth come in contact with the marked pinion teeth, an impression is left on the high part of the gear tooth. After the gear is turned 1/4 turn, or is in a convenient position for stoning, all high spots indicated by the marks are removed with a small handstone. It will be necessary to replace the bluing on the pinion teeth repeatedly, but if the bluing is applied too thickly, false impressions will be left on the teeth.

It is permissible to scrape gear teeth to remove a local hump or deformation, however, scraping of gear teeth to obtain contact is not permitted. Scraping, to obtain contact, will not be done without the approval of the Naval Sea Systems Command.

ROOT CLEARANCE.–The designed root clearance with gear and pinion operating on their designed centers can be obtained from the manufacturer's blueprints. The actual clearance can be found by taking leads or by inserting a long feeler gage or wedge. The actual clearance should check with the designed clearance. If the root clearance is considerably different at the two ends, the pinion and gear shaft will not be parallel. Provided there is still sufficient backlash, and the teeth are not meshed so closely that lubrication is adversely affected or that clearance is reduced below specified limits, the tolerance will be satisfactory.

BACKLASH.–Backlash is the play between the unloaded surfaces of the teeth in mesh on the pitch circle. Backlash increases with wear, and can increase considerably without causing trouble.

SHAFT ALIGNMENT

Under normal conditions all alignment inspections and checks, plus the necessary repairs, are accomplished by naval shipyards. Incorrect alignment will be indicated by abnormal vibration, unusual noise, and wear of the flexible couplings or main reduction gears. When misalignment is indicated, a detailed inspection should be made by shipyard personnel.

Main Propeller Shafting

Two sets of readings are required to get an accurate check of the propulsion shafting. One set of readings is taken with the ship in drydock and another set of readings is taken with the ship waterborne–under normal loading conditions. The main shaft is disconnected, marked, and turned so that a set of readings can be taken in four different positions. Four readings are taken (top, bottom, and both sides). The alignment of the shaft can be determined by studying the different readings taken. The naval shipyard will decide whether or not corrections in alignment are necessary.

Turbine Shafting

The high pressure turbine shaft and the low pressure turbine shaft are connected to their respective first reduction pinions by flexible couplings. Each of the first reduction couplings consists of two sleeves having internal teeth which mate with external teeth on a distance piece or extension shaft. One sleeve is bolted to the turbine flange and the other is bolted to the first reduction pinion flange. Lubricating oil is fed to the meshing-sleeve and distance-piece teeth from nozzles supplied with oil from the adjacent bearing. The couplings are fitted with rings which dam the oil flow through the teeth. This causes the oil level to be as deep as the tooth height and ensures lubrication to all contacting surfaces.

Flexible couplings permit axial motion and expansion of turbine rotors but will compensate for only a very small amount of misalignment; therefore, correct alignment of turbine shafts and first reduction pinion shafts is extremely important. When a new unit is installed properly, little difficulty is experienced with misalignment; however, abnormal clearance in a turbine bearing or pinion bearing will cause misalignment of the flexible coupling.

INSPECTION OF MAIN ENGINE REDUCTION GEARS

The inspections mentioned here are the minimum requirements only. Where defects are suspected, or operating conditions so indicate, inspections should be made at more frequent intervals.

To open any inspection plates or other fittings of the main reduction gears, permission should first be obtained from the engineer officer. Before replacing an inspection plate, connection, or cover which permits access to the gear casing, a careful inspection shall be made by an officer of the engineering department to ensure that no foreign matter has entered or remains in the casing or oil lines. If the work is being done by a repair activity, an officer from the repair activity must also inspect the gear casing. An entry of the inspections and the name of the officer or officers must be made in the Engineering Log. The inspections required on the main engine reduction gears are similar to the inspections shown on the Maintenance Index Page, figure 3-1.

NAVAL SHIPYARD OVERHAUL

During shipyard overhauls, the following inspections should be made:

a. Inspect condition and clearance of thrust shoes to ensure proper position of gears. Blow out thrusts with dry air after the inspection. Record the readings. Inspect the thrust collar, nut, and locking device.

b. If turbine coupling inspection has indicated undue wear, check alignment between pinions and turbines.

c. Clean oil sump.

"SEVEN YEAR" INSPECTION

When conditions warrant or if trouble is suspected, a work request may be submitted to a naval shipyard to perform a "seven year" inspection of the main reduction gears. This inspection includes clearances and condition of bearings and journals; alignment checks and readings; and any other tests, inspections, or maintenance work that may be considered necessary.

Naval Sea Systems Command authorization is not necessary for lifting reduction gear covers. Covers should be lifted when trouble is suspected. An open gear case is a serious hazard to the main plant, therefore, careful consideration of the dangers of uncovering a gear case must be balanced against the reasons for suspecting internal trouble, before deciding to lift the gear case. The seven-year interval may be extended by the type commander if conditions indicate that a longer period between inspections is desirable.

System, Subsystem, or Component	Reference Publications
Reduction Gears	

Bureau Card Control No.					Maintenance Requirement	M.R. No.	Rate Req'd.	Man Hours	Related Maintenance
MB	ZZZFGE5	35	5025	Q	1. Inspect the reduction gear including spray nozzles.	Q-1	EO MM1 MM3	 1.0 1.0	None
MB	ZZ2FSC1	65	4290	Q	1. Measure main shaft thrust clearance.	Q-2	EO MM1 MM2	 0.3 0.3	None
MB	ZZZFGE1	84	5064	S	1. Inspect and clean oil sump and reduction gear casing.	S-1	EO MM1 MM3 2FN	 5.0 6.0 12.0	None
MB	ZZ1FCW4	65	A188	A	1. Inspect flexible couplings. Measure clearances.	A-1	MMC MM1 2FN	2.0 8.0 16.0	None
MB	ZZZFGE5	78	6669	A	1. Sound and tighten foundation bolts.	A-2	FN	1.0	None

98.171

Figure 3-1.—Maintenance Index Page.

FULL POWER TRIALS

The correction of any defects disclosed by regular tests and inspections, and the observance of the manufacturers' instructions, should ensure that the gears are ready for full power at all times.

Before Trials

In addition to inspections which may be directed by proper authority, open the inspection plates, examine the tooth contact, the condition of teeth, and the operation of the spray nozzles. It is not advisable to open gear cases, bearings, and thrusts immediately BEFORE trials.

After Trials

In addition to the inspections which may be directed by proper authority, open the inspection plates, and examine the tooth contact and the condition of the teeth to note changes that may have occured during the trials. Running for a few hours at high power will show any possible condition of improper contact or abnormal wear that would not have shown up in months of operation at lower power. Check the clearance of the main thrust bearing.

SAFETY PRECAUTIONS

1. If there is churning or emulsification of oil and water in the gear case, the gear must be slowed down or stopped until the defect is remedied.
2. If the supply of oil to the gear fails, the gears should be stopped until the cause can be located and remedied.
3. When bearings have been overheated, gears should not be operated, except in extreme emergencies, until bearings have been examined and defects remedied.
4. If excessive flaking of metal from the gear teeth occurs, the gears should not be adjusted, except in an emergency, until the cause has been determined.
5. Unusual noises should be investigated at and the gears should be operated cautiously until the cause for the noise has been discovered and remedied.
6. No inspection plate, connection, fitting, or cover which permits access to the gear casing should be removed without specific authorization by the engineer officer.
7. The immediate vicinity of an inspection plate should be kept free from paint and dirt.
8. When gear cases are open, precautions should be taken to prevent the entry of foreign matter. The openings should never be left unattended unless satisfactory temporary closures have been installed.
9. Lifting devices should be inspected carefully before being used and should not be overloaded.
10. When ships are anchored in localities where there are strong currents or tides, precautions should be taken to lock the main shaft.
11. Where the rotation of the propellers may result in injury to a diver over the side, or in damage to the equipment, propeller shafts should be locked.
12. When a ship is being towed, the propellers should be locked, unless it is permissible and advantageous to allow the shafts to trail with the movement of the ship.
13. When a shaft is allowed to turn or trail, the lubrication system must be in operation. In addition, a careful watch should be kept on the temperature within the low pressure turbine casing to see that windage temperatures cannot be built up to a dangerous degree. This can be controlled either by the speed of the ship or by maintaining vacuum in the main condenser.
14. The main propeller shaft must be brought to a complete stop before the clutch of the turning gear is engaged. (If the shaft is turning, considerable damage to the turning gear will result.)
15. When the turning gear is engaged, the brake must be set quickly and securely to prevent the shaft turning and damaging the turning gear.
16. When a main shaft is to be unlocked, precautions must be taken to disengage the turning gear clutch, before releasing the brake. If the brake is released first, the main shaft may begin to rotate and cause injury to the turning gear and to personnel.

17. In an emergency, where the ship is steaming at a high speed, the main shaft can be stopped and held stationary by the astern turbine until the ship has slowed down to a speed at which the main shaft can be safely locked.

18. Where there is a limiting maximum safe speed at which a ship can steam with a locked propeller shaft, this speed should be known and should not be exceeded.

19. Before the turning gear is engaged and started, a check should be made to see that the turning gear is properly lubricated. Some ships have a valve in the oil supply line leading to the turning gear. The operator should see that a lube oil service pump is in operation and that the proper oil pressure is being supplied to the turning gear before the motor is started.

20. It should be definitely determined that the turning gear has been disengaged before the main engines are turned over.

21. While working on or inspecting open main reduction gears, the person or persons performing the work should not have any article about their person which may accidentally fall into the gear case.

22. Tools, lights, and mirrors used for working on or inspecting gears, bearings, etc. should be lashed and secured to prevent accidental dropping into the gear case.

CHAPTER 4

STEAM-DRIVEN GENERATORS

Electrical power, a vital part of today's modern Navy, is provided throughout naval ships by steam-driven turbogenerators. Many factors, such as maximum power requirements, safety, and reliability, determine the number of generators that are installed aboard each class of ship. With the ever increasing use of electrical and electronic components of advanced design, the demand for turbogenerator reliability is greater than ever.

Inspection, maintenance, and repair of steam-driven generators—all factors which contribute to reliability—are discussed in this chapter. Before studying the material presented in this chapter, you may find it helpful to review the operation of steam-driven generators given in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

TURBOGENERATOR MAINTENANCE

Satisfactory operation of turbogenerators depends largely on the care that is given the units. All tests, inspections, preventive maintenance, and repairs should be performed in accordance with the requirements of the Planned Maintenance System and applicable technical equipment manuals.

One operating trouble that may result from improper maintenance is vibration. Before going into the actual details of maintenance, therefore, we will take a look at some of the causes of vibration.

VIBRATION

If excessive vibration occurs in a turbogenerator, a thorough investigation should be made to determine the cause or causes. If the trouble is not promptly located and corrected, the casualty will probably become more serious and may result in complete failure of the unit.

All rotating parts are balanced statically and dynamically before the unit is installed. Excessive vibration is not usually the result of improper balancing. Rather, excessive vibration can almost always be traced to one or more of the following defects which result from improper maintenance:

1. Loose foundation hold-down bolts on the turbine or reduction gear.
2. A rumbling noise probably indicates the presence of water in the casing.
   a. Excessive boiler priming.
   b. Inadequate casing drainage.
3. Rubbing of gland seal rings (turbine).
4. Unevenly heated rotor.
5. Wiped bearing or excessive oil film clearance.
6. Damaged blading.
7. Turbine standing idle for more than 5 minutes (in some plants) without being spun, could bow the rotor temporarily.
8. Misalignment between turbine and generator.

If a turbine vibrates excessively, the following steps should be taken:

1. Examine all journal bearings and renew any bearings that have excessive clearances.
2. Examine the thrust bearing. Renew the thrust bearing if the clearance is excessive.
3. Inspect the turbine rotor for signs of damage, if inspection ports are provided.
4. Check the shaft packing rings for heating colors. If the clearance is too small, the vibration

will become worse and the shaft will overheat. Stop and renew packing rings.

5. Check the shaft coupling bolts.

6. Check the coupling alignment.

7. Look for loose bolts in the unit. Replace or tighten bolts as necessary.

8. After completing steps 1 through 7, reassemble the unit and operate it at normal speed to see if the excessive vibration has been eliminated.

If the turbine continues to vibrate excessively, it is probably out of balance. In this event, a balance test must be made. Portable vibrational test equipment, available on tenders and repair ships, may be used to make a balance test with the turbine in place; or the unit may be tested at a shipyard. Only experienced personnel should be permitted to balance a turbogenerator, and the instructions of the manufacturer must be followed carefully. Details of the balancing must be recorded.

TURBINE MAINTENANCE

After each extended period of steaming, and at least once each quarter, the following tests and inspections should be made.

The turbine foundation and the unit itself should be inspected for loose or broken bolts and nuts. If any are found, they should be tightened or replaced. Broken or loose foundation bolts can lead to serious vibration or misalignment.

All sliding contacts and pivot points in the governor and the overspeed tripping mechanism should be kept well oiled and free of dirt, paint, and rust, so that there will be no sticking which will prevent the devices from functioning properly.

When a turbine is new, or after extensive repairs have been made to a unit, the oil in the sump should be renewed or purified frequently. For normal operation, renew the oil or purify it often enough to ensure that it is clean and free of water, sediment, and other foreign matter which would damage the bearings or gears. When the oil is pumped out of the sump for any reason, the inspection plates should be removed and the sump tank inspected. The sump should be wiped with lint-free rags. Extreme care ould be taken to ensure that no rags or other foreign matter are left in the sump when it is closed.

When it is necessary to flush out the lubrication system, operate the turbine slowly for several minutes, using an approved flushing oil to thoroughly clean out all lines, bearings, etc. Then drain out the flusing oil and fill the sump to the normal level with clean oil.

Gland Packing Maintenance

One of the reasons for losing vacuum in the auxiliary condenser is that the gland packing is excessively worn or badly fitted. The gland packing used in generator turbines may be carbon packing, labyrinth packing, or a combination of both. When ordering carbon or labyrinth packing, always order complete sets.

To prevent leakage of steam from (or air into) the turbine, the joints and bores of carbon packing must be fitted accurately. Fitting packing on turbine shafts is a difficult job which must be done by hand after the original installation. A jig and gage may be used to reduce the time required and to simplify the job of fitting carbon packing. Detailed instructions on how to construct the jig and gage and on how to use them are given in *NAVSHIPS Technical Manual* and in chapter 2 of this training manual.

To remove the carbon packing rings, remove the bolts from the upper halves of the packing boxes at horizontal and circumferential ioints. Carefully lift the upper halves vertically to prevent damage to the sealing surfaces. Unhook the spring from the clip and remove the upper segment of the packing ring. Then remove the two remaining segments and pull the spring around the shaft.

To reassemble the packing, push the spring through the lower half of the packing box. Install the two lower segments between the spring and the shaft. Install the top segment and hook the spring into the clip. Ensure that the sealing side of each ring is installed against the proper side of the cell.

The individual segments are marked on each end; the packing ring when assembled must have corresponding markings adjacent to each other. The segments are not interchangeable within the same rings or in other rings. Complete rings may be interchanged in the various cells with other similar rings but the sealing side must always be assembled as indicated in the manufacturer's technical manual.

Turbine Casing Joints

The horizontal joint of some generator turbines is grooved, in the lower half, to provide a means for pressure-pumping the groove with a sealing compound. These grooves shall not be filled except in case of emergency. They shall not be filled during routine overhaul unless the flange surfaces are in poor condition, and time and facilities do not permit resurfacing. Only approved compounds may be used to fill these grooves.

To fill the grooves, remove one end plug and the adjacent plug. Start at the end hole and pump in the sealing compound, with the gun provided, until it flows out of the adjacent hole. Now, plug the first hole and place the gun in the adjacent hole, remove the plug from the next hole and fill the next section of the groove in the same manner. Continue until the entire groove is filled. With the gun in the next to last hole, and the sealing compound flowing from the last hole, plug the end hole and put pressure on the entire groove. Then remove the gun and plug the next to last hole.

Once this operation has been started, it must be carried out rapidly and continuously in order to finish filling the groove before the sealing compound hardens.

Rotor Clearances

Axial flow turbines are usually provided with an opening in the casing for the purpose of checking blade clearance. As with main propulsion turbines, a tapered gage is inserted between the nozzle diaphragm and the adjacent row of blades for measurement of blade clearance. If the blade clearance is found to be outside the limits prescribed by the manufacturer, the position of the rotor should be adjusted by inserting a filler piece in the thrust bearing before the unit is operated again. After each rotor adjustment, the unit should be rotated by hand to make sure that there is no rubbing, binding, or undue friction. The gear tooth contact of the reduction gear must also be checked.

Nozzle Diaphragm Maintenance

Nozzle diaphragms (fig. 4-1) are installed as part of each stage of a pressure-compounded impulse turbine. In order to seal against steam leakage, labyrinth packing and in a few cases carbon seals are used between the inner bore of the nozzle diaphragm and the rotor.

To inspect or renew the labyrinth packing in a nozzle diaphragm, it is necessary to remove the upper half of the turbine casing. When the casing is lifted, the upper half of the diaphragms and the labyrinth packing will remain in the upper half of the turbine casing. When the casing has been moved to a convenient location, the segments of labyrinth packing can be removed by pushing them around in their grooves, away from the stop pin.

Although repairs of labyrinth packing in nozzle diaphragms are normally performed by shipyard, tender or repair ship personnel, Machinist's Mates should be familiar with the procedures involved. All necessary information is available in the manufacturer's technical manual.

96.19

Figure 4-1.—Nozzle diaphragm with labyrinth packing.

Corrosion

The turbine casing should be inspected, especially near glands and in locations where water may collect in pockets or in lagging. Experience has shown that where water or dampness is permitted to remain in contact with the casing, corrosion can seriously weaken the casing. Drain holes provided in pockets must be kept open and should be of sufficient size. When corrosion is evident, the lagging should be removed and the surface of the casing should be scraped down to good metal, then dried, and painted with two coats of approved paint. Lagging should then be replaced and steps taken to prevent recurrence of corrosion.

Internal corrosion, and rusting that impairs reliability and economy of turbine operation, can be almost entirely prevented by continuing operation of air ejectors for a short time to dry the machine after it has been shut down, and while still hot. Blade path of turbine is provided with passages to drain any condensate in inter-blade row cavities.

In some cases, serious corrosion has been caused by chemical action. Inspect interiors as frequently as possible, and if corrosion has begun, its cause should be determined and eliminated. A mirror can be used to aid inspection of interior of turbine; exercise care to ensure that it is not dropped inside turbine. Reference should be made to *Naval Ships Technical Manual* for required inspection intervals.

REDUCTION GEAR MAINTENANCE

Turbogenerator reduction gears are generally of the single-reduction, single helical type, having a reduction of about 8 to 1. In three-bearing designs, the pinion is forged and cut integral with its shaft. One end of the pinion shaft is provided with a flange that bolts rigidly to the turbine shaft, and one end of the turbine rotor is supported by the pinion bearing. The other end of the pinion shaft has an extension on which is assembled the high speed thrust bearing. In four-bearing designs, the pinion shaft is flexibly coupled to the turbine shaft, with two bearings supporting each shaft. A flexible coupling of the double-ended dental type is usually employed in these four-bearing designs.

The gear wheel is forged, shrunk, and keyed to the shaft. One end of the shaft is coupled to the generator shaft, and part of the weight of the generator rotor is carried by the gear bearing at that end. The turbine end of the gear shaft is extended to carry the worm gear; the worm gear drives the oil pump and the governor.

The gear casing is of fabricated construction and is split at the horizontal centerline of the rotor. The bearing seats are welded integral with the lower half of the gear casing. In most installations, cross members and ribs are welded into the casing to form a rigid structure for supporting the rotating elements, the oil pump, and the thrust bearing.

The amount of wear of gear bearings shall not be allowed to become sufficiently great as to cause incorrect tooth contact. For proper operation of gears, it is essential that the total tooth pressure be uniformly distributed over the total length of the tooth faces. This can only be accomplished by accurate alignment and strict adherence to the designed clearances.

Gear misalignment occurring after prolonged operation is usually traceable to a sudden wearing or wiping of the bearings. This misalignment can be corrected by bearing replacement, but the installation of new bearings requires a thorough check on the alignment of the gear mesh to assure at least 90 percent contact. Replacement of bearings that exceed tolerances because of normal wear can be very detrimental to the operation of the turbogenerator. The gears wear to essentially a conjugate tooth form after prolonged operation; therefore, replacement of the bearings may cause the gears to operate at different center distances, and noisy operation may result. Whenever bearings are replaced, the gear alignment must be checked and any corrective action should be accomplished by competent naval repair personnel.

Initial pitting of gear tooth faces during the early operation of the unit in service may be caused from poor alignment or machining errors in gear tooth profile and helices. The pitting will be localized and indicate the tooth areas subjected to excessive load concentrations. Such conditions should be corrected or progressive pitting will continue and general deterioration can occur. Minute high spots in the gear tooth produced by gear hobbing or finishing techniques will also cause initial pitting, but in this case, the pitting will be distributed over the active face and the pitting should cease with continued service operation. In order to properly evaluate the cause of pitting and whether or not it is progressive, the necessity for keeping complete and adequate records cannot be over emphasized.

Where pitting of the elements occurs, metal particles from the pitted areas may be entrapped in the mesh forming raised and depressed areas. To remove the high spots, a fine grade of carborundum stone should be used. Files and coarse stoning can damage the tooth contour and should not be used.

Another source of damage to the gears is the presence of foreign particles in the lubricating oil. The continued passage of these particles will destroy the original involute tooth profile. Noisy operation will result due to the dynamic forces produced by tooth tips contacting the wear shoulder in the flanks of the mating gear teeth. Such noise is most pronounced under lightly loaded conditions when the oil film thickness of the bearing causes the gear elements to operate at minimum center distance. Under heavy loads, the bearing oil film thickness diminishes and the gears operate under maximum center distance. Under the heavy load conditions, the mating elements withdraw from each other causing the interference of tooth tips of one element with the wear shoulder of the mating tooth to be diminished. This type of wear results in the gears having to be replaced or recut.

Foreign particles will also cause high spots which have a highly polished appearance after prolonged operation. Such areas of heavy contact can eventually result in fatigue failure of the highly loaded portion of the tooth. Only experienced personnel should make corrections to the tooth profile to alleviate these conditions.

The reduction gear was carefully assembled, and aligned for even tooth and bearing loadings, to ensure that it would operate with a minimum of maintenance.

Almost all tests, inspections, maintenance, and repair procedures for main reduction gears also apply to turbogenerator reduction gears. A visual inspection of the tooth contact of the pinion gear and main gear should be made periodically and a record of the condition of the teeth should be kept.

Inspect and perform maintenance on the pinion and main gears as follows:

1. Inspect for proper tooth loading by noting if gear tooth marking is relatively even across face of each tooth.

2. Check all teeth for cracks, pitting, chipped areas, and evidence of foreign matter passing through gear train or imbedded in teeth. If chipping is not extensive, carefully stone down sharp edges to prevent further damage. Remove all foreign matter from teeth and carefully stone down any high spots.

3. Remove oil nozzles and clean with mineral spirits or approved substitute whenever routine inspection is made, and more often if they become clogged. Blow dry, verify that nozzles are completely clear, and replace.

4. Remove and clean oil breather filters, periodically, using mineral spirits or approved substitute by dipping it in clean oil and allowing it to drain before replacement.

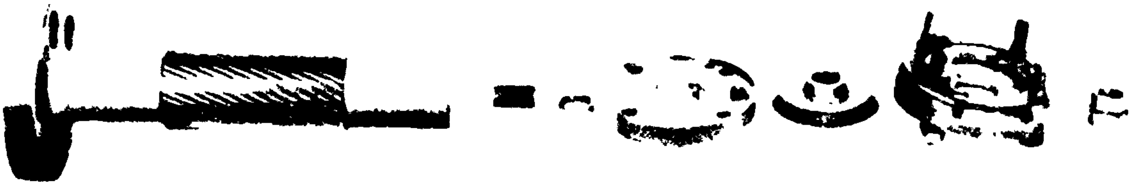
BEARING MAINTENANCE

In general, repairs of bearings for propulsion turbines and for ship's service turbogenerators are performed similarly. Turbogenerator journal bearings, journals, and thrust bearings (thrust collars and thrust plates) must be inspected and clearance readings taken at regular intervals, to ensure that clearances are within allowable tolerances.

Most journal bearings are cylindrical and of the steel-backed, babbitt-lined type. They are split on the horizontal centerline to facilitate installation and removal. Some newer turbogenerators employ the pivoted segmental journal bearing. Most journal bearings are prevented from rotating by setscrews or by dowel pins. Journal bearings that are installed properly, and operated properly, and receive sufficient preventive maintenance will give many years of satisfactory service. The manufacturer's technical manual and *NAVSHIPS Technical Manual* contain information on the operation and maintenance of these bearings.

On most turbogenerators, the reduction gear casing must be removed before the pinion gear bearings, the main gear bearings, and the slow speed thrust bearing are accessible. The forward turbine bearing, the generator pedestal bearing, and the high speed thrust bearing can be removed by lifting the bearing caps and removing the bearings.

Many turbogenerator thrust bearings differ radically from main propulsion thrust bearings. On many installations, the thrust bearing (fig. 4-2) consists of a thrust collar and two thrust



96.20

Figure 4-2.—Collar and plate type thrust bearing.

plates. The thrust collar is locked to the pinion shaft and the thrust plates are bolted to the casing. The axial position of the thrust collar is determined by the spacer or shim, which is ground to the desired thickness at assembly. The total running clearance between the stationary plates and the rotating element of the thrust bearing should be obtained from the manufacturer's equipment manual. This clearance is adjusted by removing or adding shims to the two stationary thrust plates.

The axial position of the generator rotor is maintained by the thrust faces on the gear bearings, which bear against the thrust surfaces machined on the ends of the gear hub. Clearance is adjusted by means of a filler piece between the thrust shoulders of the gear bearings and the gear casing. The low speed thrust bearing will experience little wear, under normal operating conditions. The original clearance will change very little in service. If the thrust surfaces do wear, as the result of faulty operation or improper lubrication, they should be replaced or rebabbitted when the total running clearance exceeds the manufacturer's recommendations. Instructions for adjusting the thrust clearance or renewing the thrust bearings are given in the manufacturer's technical manual. The applicable blueprints and technical manuals should be carefully checked before attempting any adjustments or repairs to these bearings.

In most installations, to remove the high speed thrust bearing for inspection or repair, proceed as follows:

1. Remove the thrust bearing cover, upper and lower halves.
2. Remove the four bolts from the outer thrust plate.
3. Remove the outer thrust plate.
4. Remove the locknut and the securing nut from the pinion shaft.
5. The thrust collar and the inner thrust plate can now be removed.

If the high speed thrust bearing needs adjustment, the following procedure may be followed:

1. Remove the thrust bearing cover.
2. Remove the four bolts from the outer thrust plate.
3. Remove the outer thrust plate.
4. Move the turbine rotor axially in the direction of the generator, until the first-stage turbine wheel hits against the nozzles.
5. The distance between the face of the thrust collar and the land of the inner thrust plate is then set to the clearance desired (between the first-stage turbine wheel and the nozzle), plus the running clearance of the thrust bearing. The clearance is obtained by machining the locating spacer to the proper thickness.
6. Replace the locating spacer and lock the thrust collar in position on the shaft.
7. Replace the outer thrust plate.
8. Take a thrust clearance reading to determine total clearance of the thrust bearing.
9. If the thrust reading is satisfactory, replace the bearing cover and rotate the unit by hand. If there is no undue friction or binding, the unit may be turned by steam.

After the high speed thrust bearing has been set, the position of the generator rotor is set so that the face of the gear is centered with the face of the pinion—when both are in a loaded position. The turbine rotor is moved in the direction of the generator, and the generator rotor is moved in the direction of the turbine as far as the thrust bearings will permit; the gear rotor is set in this position and the proper clearance is obtained by using the proper thickness of shims behind the thrust shoulder of the gear bearings.

On turbogenerator installations that use a Kingsbury thrust bearing, the tests, inspections, maintenance, and repairs are carried out in the same manner as are those for main propulsion turbines, described in chapter 2 of this training manual, in the manufacturers' technical manuals, and in *NAVSHIPS Technical Manual.*

LUBE OIL SYSTEM MAINTENANCE

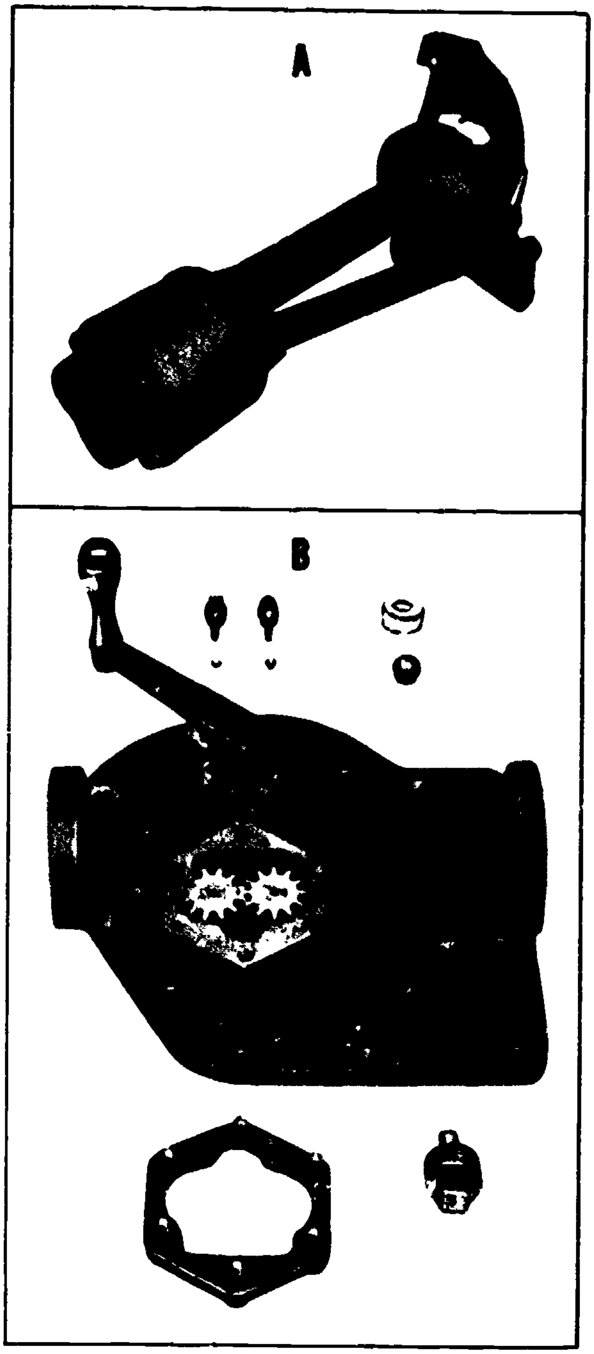
Oil pressure for operating the constant speed governor and for lubricating the bearings and gears is supplied by a gear type pump (part A, fig. 4-3) which is located in the base of the gear casing and driven from the low-speed gear shaft.

The separate hand-operated oil pump (part B, fig. 4-3) for supplying oil to the bearings and to the valve gear for starting, is located on the gear casing.

Some ships include a third oil pump, which is driven by an electric motor. This pump, mounted on the generator foundation, is used to supply lube oil to the generator while starting or securing; it is normally started and stopped manually. The pump may also be used as an emergency pump. Once the generator is running, the electric pump may be set so that if the oil pressure should fall to a predetermined point (below normal) a pressure sensing device located in the oil system will start the electric pump.

A system of oil piping conveys the oil to the speed governing mechanism and the bearings and gears. A diagram of the oil piping can be found in the manufacturer's technical manual.

All of the oil supplied to the bearings, except that supplied by the hand pump before starting, passes through the oil manifold and the strainer. The strainer assembly is of the duplex type; the shift lever diverts the oil to only one strainer at a time. The level carries a notation or an arrow to enable the operator to know which strainer is in use. The arrow or notation points to the strainer in use and all oil is passing through this element. A spring-loaded relief valve and a hand valve are built into the manifold. The relief valve is set to function at approximately 50 psig. The hand valve controls the flow of oil to the gear and bearings. It is slotted so that all oil flow cannot be shut off. The hand valve should be set to maintain about 8 to 10 psig on the lube oil system.



96.21

Figure 4-3.—A. Main oil pump. B. Hand-operated oil pump.

In connection with the lube oil system, the following instructions should be observed:

1. See that the oil and lube oil system are clean and the proper oil level is maintained.

2. Maintain an ample reserve supply of oil for emergency use and for making up any deficiency.

3. Periodically take samples of oil from the lube oil system and have them analyzed.

4. Do not allow water to mix with the oil. Any water accumulating in the sump tank can be removed by using the purifier. The source of water must be determined and eliminated.

5. Calibrate all pressure gages at least quarterly or at any time there is reason to believe that the gages should be calibrated. Throttle the gage shutoff cocks to reduce needle vibration and consequent wear on the internal mechanism. Inspect gage lines for tight connections and ascertain that there are no kinks in the tubing.

6. Check the oil cooler for leaks daily. This can be done by taking a sample of water from the discharge side of the cooler and checking for the presence of oil.

If the oil supply to the bearings is interrupted, stop the unit immediately and then take the necessary steps to restart the oil circulation. These steps may include any one or a combination of the following:

1. Clean the strainers.
2. Repair any broken line.
3. Remove any obstruction from line.
4. Add oil to the sump tank.
5. Increase the oil pressure by increasing the setting of the relief valve.

If a bearing overheats, the unit should be slowed down, but kept turning over at a low speed until the bearings have cooled sufficiently to prevent the bearing metal from adhering to the shaft.

If the oil pressure fails below normal, immediately examine the bearings, the lines, the strainers, and the oil level in the sump tank. If temporary repairs cannot be made satisfactorily with the unit operating, the unit must be secured.

There are several causes for OIL LEAKAGE in a turbogenerator. The majority of these causes can be remedied by operating personnel. The following paragraphs list causes of leakage with corrective measures to be taken:

1. If oil leakage occurs where a shaft emerges from a casing, the oil seals or deflectors may be excessively worn or damaged, and must be replaced to stop the oil leakage.

2. The oil return holes may become clogged with residue from the oil. As the bearings wear and the holes become clogged with dirt, a greater quantity of oil than the holes can accommodate will pass through the bearings. If the bearings are badly worn, the only remedy is to fit new bearings. When the bearings are disassembled for inspection or overhaul, the oil passages and oil return holes should be cleared of all sediment.

3. If the relief valve setting is too high, the oil pressure will be excessive and may cause oil leaks at the bearing ends; if so, the relief valve setting can be slightly reduced to allow some of the oil to be bypassed back to the sump tank.

4. Oil leakage frequently occurs at flanges in the discharge piping. In some instances, tightening the flange will stop the leak. In others, the gasket must be renewed. In extreme instances, the flanges must be taken apart and the contact surfaces must be machined true.

When the turbogenerator is operating, the lube oil strainers must be cleaned at least once each watch. Excessive pressure drop across the strainer indicates the need for cleaning. Two strainers are installed for each unit but only one strainer is in the operating position. The idle strainer can be removed and cleaned. When cleaning a strainer, care should be taken to remove any metal particles adhering to the magnets in the strainer basket. When replacing a strainer, ensure that the inner circular face is against its proper shoulder. If the strainer does not readily fit in the manifold body, do not try to tighten the cover plate; fit the strainer properly against its shoulder.

After putting the cover plate in place, fill the idle strainer with oil by opening the vent and turning the transfer valve slightly toward the idle strainer until oil comes out of the vent. After you have closed the vent valve, the strainer is ready to be put in service.

Any change in the oil temperature drop through the oil cooler, when all other conditions remain the same, is a positive indication that the water or oil side of the cooler requires cleaning. Even without this indication, the oil cooler tube bundle should be cleaned at regular intervals. To clean the cooler proceed as follows:

1. Turn the cooler bypass valve to full bypass position. Shut off the water to the cooler and drain the water side and then the oil side of the cooler.
2. Remove the main head and the floating (lower) head.
3. Remove the gland and the packing.
4. Press upward on the floating (lower) tube sheet. Grasp the main tube sheet when it passes out of the shell and draw the tube bundle straight up, taking care not to let it get out of direct line with the cooler bore and thus damage the baffles.
5. The external surfaces of the oil cooler may then be cleaned with a jet of hot water. The internal surfaces of the tubes should be cleaned with a round bristle brush (never use a wire brush for this purpose). The internal surfaces should be cleaned while still wet; if the surfaces are allowed to dry, the salt water deposits will be difficult to remove.
6. In replacing the tube bundle, care should be taken that the baffles do not catch on the shell, as this will cause them to carry the entire weight of the tube bundle.
7. Vent the air from the water and oil circuits, after circulation has been started.
8. When the cooler is put in use (after reassembly), the gaskets and packing should be carefully checked for leaks. When it has been determined that there are no leaks, the cooler is ready for routine use.

A LUBE OIL LOW PRESSURE ALARM is installed on all turbine-driven generators. The alarm contactor is located in the lube oil line leading to the bearings. The contactor is connected to an audible alarm and to a signal light; the arrangement is such that the contactor will close an electrical circuit to the alarm, when excessively low lube oil pressure occurs. The circuit is closed when the unit is not in operation. Therefore, a manual switch must be opened to keep the alarm from sounding. When the unit is brought up to speed, the manual switch must be closed to make the alarm operative.

The contactor is set at the factory to operate when the oil pressure drops to 4 psig and this setting should be maintained. The instructions contained in the manufacturer's technical manual should be followed when making any adjustment to the contactor.

There are at least two pressure gages installed to indicate oil pressures throughout the system.

The high pressure gage indicates the oil pressure delivered by the pump. This is the pressure that is applied to the governor and to the oil strainers. This gage is labeled OIL PUMP PRESSURE and the normal reading is from 50 to 100 psig depending on the type of governor used.

The low pressure gage indicates the oil pressure in the lube oil lines to the bearings and the reduction gears. This gage is labeled BEARING OIL PRESSURE and the normal reading for this gage is about 8 to 10 psig.

ALIGNMENT

Successful operation of the turbogenerator set requires accurate alignment of the entire unit. Proper alignment of the unit requires accurate setting of the gear casing, turbine casing, and adjustment of bearings. This is essential to obtain satisfactory tooth contact and proper load distribution on the bearings. It is also necessary that the pinion and turbine shafts, when coupled together, run true with one another. Incorrect alignment may cause vibration, unsatisfactory contact of the gear and pinion teeth, unsatisfactory operation—and finally, complete failure of the unit.

Under normal circumstances, alignment of turbogenerators will be done by shipyard, tender, or repair ship personnel. If the services of a shipyard, tender, or repair ship are not available, the following checks may be made by ship's force.

1. Check all foundation bolts to see that they are tight.
2. Check tooth contact by applying very thin layers of prussian blue to several gear teeth

and applying red lead to several pinion teeth. Next rotate the pinion in a clockwise direction (when looking at the unit from the turbine end). The resulting contact markings should cover at least 90 percent of the length of the tooth and be equally heavy at both ends of the helix.

3. If the tooth contact is unsatisfactory, the extent of bearing wear can be determined by measuring the crown thickness of the bearings. The clearances of the high speed and the low speed thrust bearings should be measured.

4. If it is found that one of the pinion bearings or one of the main gear bearings is worn more than .002 inch more than the other bearing, replace or restore bearings to design clearance. If the crown thickness of these bearings are satisfactory and misalignment is suspected, the unit will have to be realigned by shipyard, tender, or repair ship personnel. The designed and maximum clearances of bearings are shown on applicable blueprints and given in the manufacturer's technical manuals. If blueprints and technical manuals are not available, it is recommended that the limits given in *NAVSHIPS Technical Manual* be followed. These limits are to be used as a guide; bearings should be renewed or other applicable repairs should be made if a smaller amount of bearing wear causes vibration, misalignment, or other abnormal operating conditions.

CONTROL AND SAFETY DEVICES

Turbine-driven generators are equipped with the following control and safety devices:

1. Constant speed governor
2. Overspeed trip
3. Manual trip
4. Lube oil low pressure alarm
5. Relief valve
6. Sentinel valve
7. Back-pressure trip
8. Gland seal steam regulators

The principles of operation of a CONSTANT SPEED GOVERNOR are explained in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D. The following paragraphs deal only with maintenance and adjustment of constant speed governors.

Maintenance consists mainly of keeping all moving parts free of paint, rust, and dirt so that there will be no undue binding or friction. The governor is set at the factory and the setting should not be changed. Damaged governors should be sent to the factory for repair and adjustment.

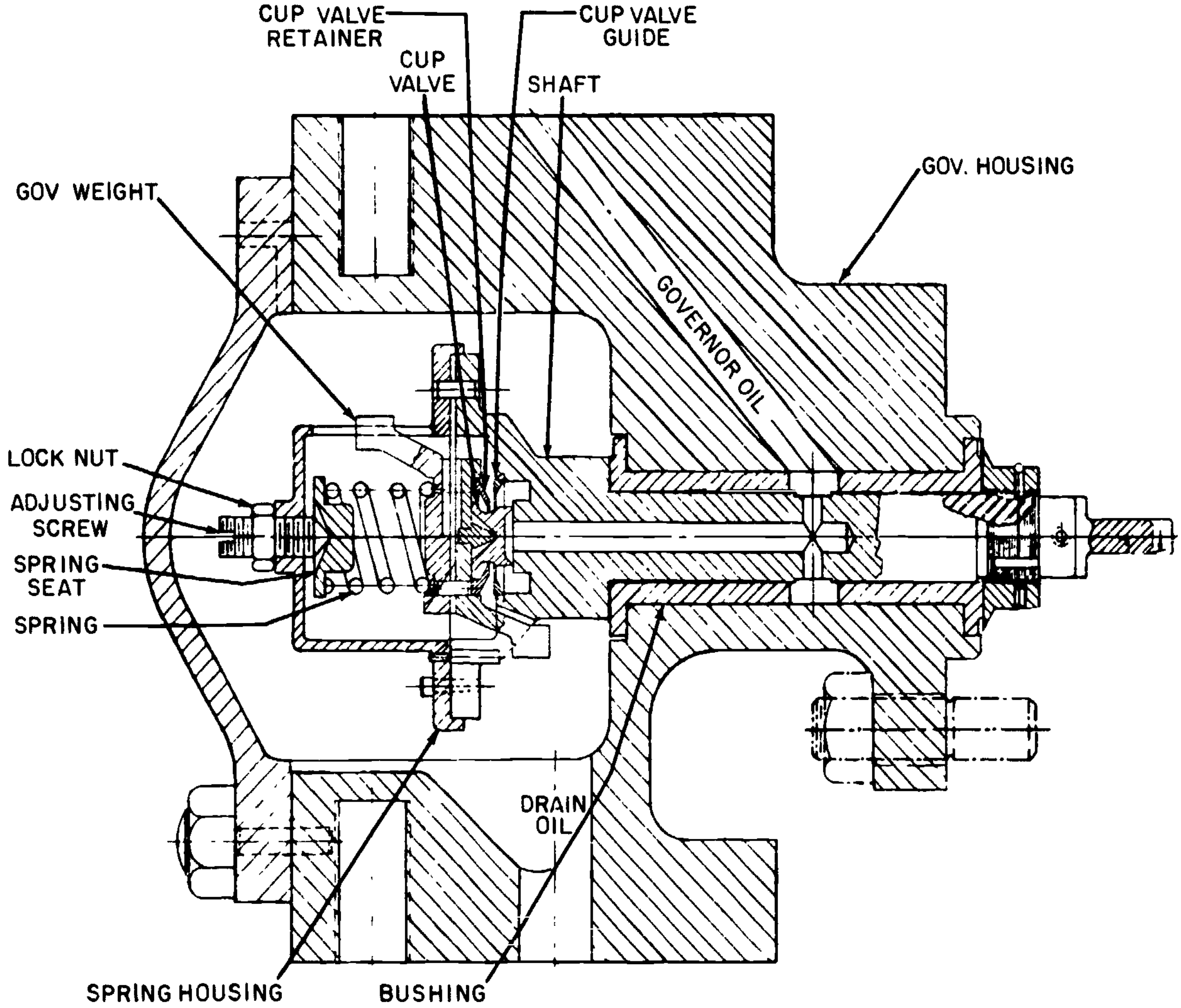
Any change in speed range or regulation should be made by adjusting the governor spring tension. REGULATION is a term used to express the change in speed that occurs with a change in load. Regulation is usually stated as a percent change in speed that occurs when passing from no load to full load, and based on full-load speed. The governor spring tension is set properly at the factory and should not be changed unless absolutely necessary.

Figure 4-4 shows one type of governor used on Navy ships. A constant speed (speed-regulating) governor is defined as a governor which, by its control and regulation of the steam admission to a turbine, automatically maintains the speed of the turbine at a predetermined rate, under all conditions of load and exhaust pressure, within the limits of design of the turbine. The governor shaft is located horizontally and is driven directly from the turbine rotor shaft through the overspeed trip body. Governors of this class are of the hydraulic relay type centrifugally controlled, using lubricating oil as the relaying medium for the actuating force.

The turbine governor was set at the factory to operate at a predetermined rate with tolerance. No adjustment or repair work should be undertaken on a constant speed governor without first carefully checking the manufacturer's technical manual for details on maintenance.

The OVERSPEED TRIP is a device which provides a means of automatically releasing the operating oil pressure under the throttle valve operating piston which allows the piston spring to close the valve. The mechanism comprises a trip of the eccentric weight shaft type, functioning as an oil release valve, mounted on the thrust end of the turbine rotor. One type of overspeed trip for turbogenerators is shown in figure 4-5.

At the predetermined speed for which the device is set, the centrifugal force overcomes the spring resistance and the plunger moves outward opening to drain the throttle valve operating oil from the cavity formed under the plunger. This



96.46

Figure 4-4.—Governor.

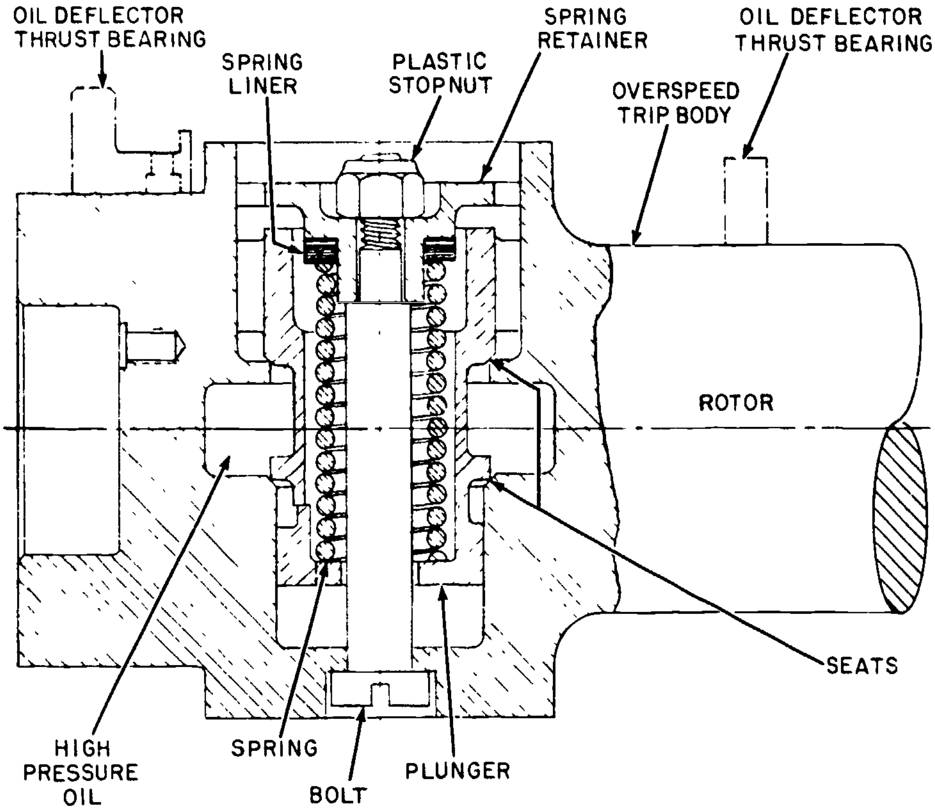
mechanism opens to drain the operating oil line leading to the throttle valve operating cylinder, and loss of oil pressure causes the turbine throttle valve to be closed by the loading spring.

Once the turbine unit has been tripped through the overspeed trip mechanism, normal turbine operation cannot be resumed until the throttle valve handwheel has been fully closed The manual trip mechanism should be in the reset position.

Overspeed trips are set at the factory and should be trouble free. If for any reason the plunger should hang up, or the tripping speed should change so that an adjustment is required, disassembly will be necessary. To obtain access to the overspeed trip, proceed as follows:

1. For a casual inspection of the overspeed trip a removable access hole is directly over the mechanism. For further inspection, cleaning, adjustment, or repairing, remove the governor and bearing cover. With these parts removed, the overspeed trip mechanism is exposed.

2. If the bolt and nut (fig. 4-5) are not in an accessible position for disassembly, it will be necessary to rotate the entire rotor a small amount. Use the rotor barring tool.



96.47

Figure 4-5.—Overspeed trip.

3. Referring to figure 4-5, remove nut, spring retainer, and spring liners. Withdraw bolt and lift out plunger and spring. Care should be used in handling the spring liners during removal.

4. The parts should be cleaned in mineral spirits, inspected for scoring or pitting and checked for freedom of operation. Make sure the seats of the plunger give a tight fit when in the closed position. Damaged parts should be repaired or replaced. Reassemble by reversing the above procedure.

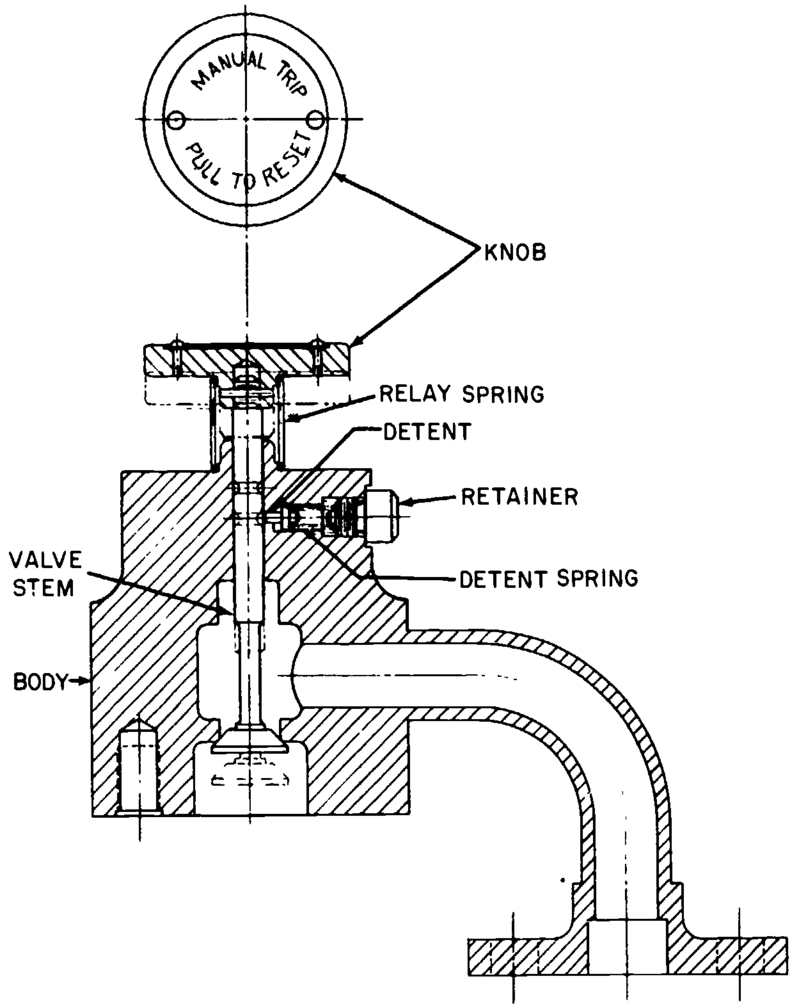
For additional details consult the manufacturer's technical manual.

The MANUAL TRIP (fig. 4-6) is installed to provide a quick means of stopping the flow of steam to the turbine in an emergency. The device also is used when securing the unit in a normal manner.

Under normal operating conditions, the parts held in the latched position by the spring loaded detent fitting into circumferential grooves machined in the valve stem ready to operate by depressing the knob. The oil supply to the throttle valve is metered so that the oil can be drained faster than it can be supplied. Whenever any of the protective devices are activated, the resulting oil pressure drop permits the spring to close the throttle valve.

To reset the MANUAL TRIP after it has tripped and has closed the throttle valve, proceed as follows: Turn the throttle valve handwheel to the valve closed position. Manually place the tripping mechanism in the closed or reset position; this closes the oil drain and allows oil pressure to build up thus permitting the throttle valve to open when the handwheel is turned in the open direction.

The trip mechanism is designed and built to give trouble free service, under normal operation, for the life of the unit. However, if foreign matter is permitted to get into the lubricating



96.48

Figure 4-6.—Manual trip.

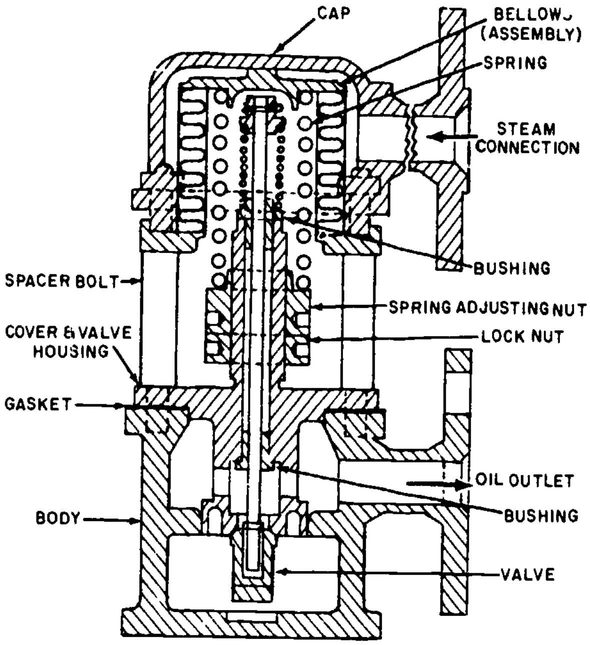
oil, it may score, or become lodged under, the valve and interfere with its operation. If the valve will not close tightly, an attempt should be made to free it with ordinary flushing by tripping the unit several times. If the valve cannot be freed in this manner, or the valve becomes scored, the mechanism will have to be removed from the unit, taken apart, and manually cleaned and inspected. To do this, consult the manufacturer's technical manual for details.

The **LUBE OIL LOW PRESSURE ALARM** is a safety device installed to warn the operator when the lube oil pressure drops to a dangerously low point. The operation of this device is described in this chapter under the heading "lube oil system maintenance." Under normal conditions, the maintenance of this device will be performed by Electrician's Mates.

To protect the turbine against excessive exhaust pressure, three devices are installed: a sentinel valve, a back-pressure tripping device, and a relief valve.

A small (usually 1/2 inch) **SENTINEL VALVE** is mounted on the upper half of the exhaust casing, to warn the operator of excessive exhaust pressure. The valve is spring loaded and set to function at 2 psig; this setting should be maintained.

Another device installed to protect the turbine against excessive exhaust pressure is the BACK-PRESSURE TRIP (fig. 4-7). The device is set at the factory to function at 5 psig; and this setting should not be changed.



96.49

Figure 4-7.—Back-pressure tripping.

When a loss of vacuum in the auxiliary condenser occurs, the sentinel valve will lift when the pressure reaches 2 psig. If the deficiency is not corrected, and the pressure continues to increase, the back-pressure trip will function to shut down the unit.

Steam exhaust pressure above 5 psig opens the trip valve. Oil then flows through trip assembly to drain and the throttle valve closes. The throttle cannot be reopened until the exhaust pressure falls to less than 5 psig at which time the trip valve closes and the oil pressure is built up under the throttle valve.

In the event that the back-pressure trip should fail to function, further protection is provided by the relief valve which will function at a pressure of 5 psig above the setting of the back-pressure trip.

The RELIEF VALVE is spring loaded and s if the exhaust pressure becomes excessive. valve is mounted on the exhaust end of the turbine, which permits the turbine to exhaust through it.

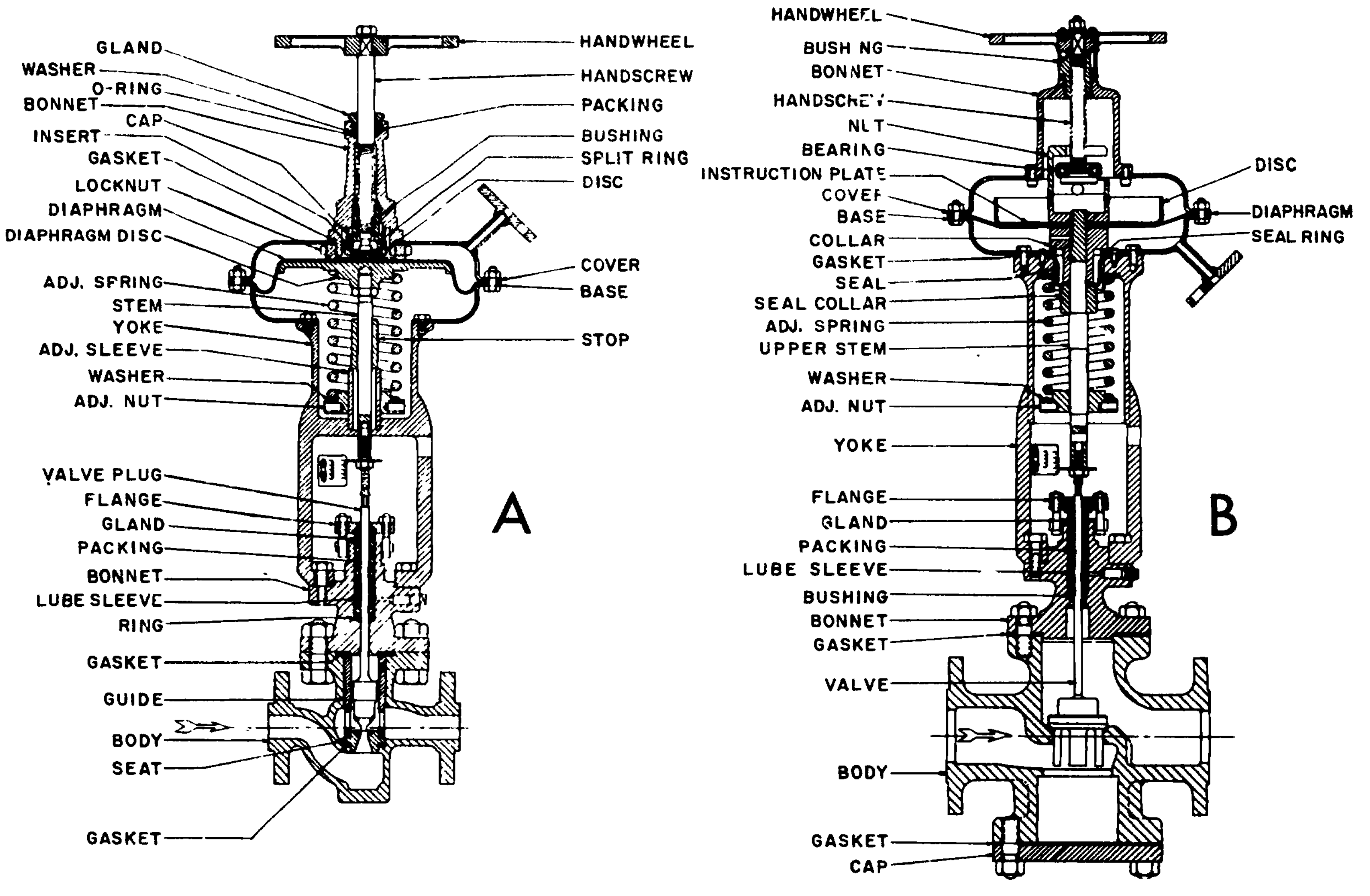
The relief valve is normally set to open at 10 to 15 psig (5 psig above the setting of the back-pressure trip). Most relief valves are fitted with a water gage. The presence of water in the gage indicates that the valve is closed and properly sealed with water.

Loss of vaccum in the auxiliary condenser is the most frequent casualty to turbogenerators. Insufficient gland sealing steam (or complete loss of gland sealing steam) is a major cause of this casualty. Most ships have AUTOMATIC GLAND SEAL STEAM REGULATORS on turbogenerators (and also on main propulsion turbines) to automatically control gland sealing steam and thus help to prevent loss of vacuum in the condensers.

The two regulator valves, shown in figure 4-8, are the main component of one type of gland sealing steam system. The SELF-OPERATED MAKE-UP VALVE (part A, fig. 4-8) is a spring loaded, diaphragm operated valve and actuator, requiring steam pressure to close. A handwheel is mounted in the top diaphragm casing for manual operation. The SELF-OPERATED UNLOADING VALVE (part B, fig. 4-8) is a spring loaded diaphragm operated valve and actuator requiring steam pressure to open. A handwheel is mounted in the top diaphragm casing for manual operation.

Steam, of sufficient quantity to seal the glands, is taken from the ship's supply line at a variable pressure. It is then reduced to 2 psig and the supply is automatically controlled by the diaphragm operated make-up valve. Excess steam, above the amount required by the existing operating conditions for gland sealing, is automatically discharged through the diaphragm operated unloading valve onto the condenser. The gland sealing steam requirements will vary over a wide range of turbine operating conditions, from light to heavy loads. The sealing steam demands will be greatest while the turbine is being started or while operating at light loads. Conversely, the sealing steam demand will be at a minimum while operating at heavy loads. With the regulating valves properly adjusted, the sequence of their operation is as follows:

With auxiliary steam being supplied to the actuator portion of the valves, the steam enters



96.50

Figure 4-8.—Gland seal steam regulators. A. Gland seal steam make-up with actuator. B. Gland seal steam unloading valve with actuator.

and flows to one side of the spring loaded diaphragms. The pressure of the sealing steam flowing through the make-up valve into the header, and then to the turbine glands, is reflected upon the upper surface of the diaphragm in the make-up valve and the lower surface of the diaphragm in the unloading valve. The diaphragm spring loadings are adjusted to a predetermined value and when the gland sealing steam pressure in the header becomes high enough to overcome the individual spring loading, the make-up valve diaphragm and its connected stem and valve plug move downward, closing the valve. At the same time, the unloading valve diaphragm, stem and valve, move upward to the open position. Then, should the gland sealing steam pressure fall below the operational requirements, this decrease in pressure is reflected upon the upper surface of the diaphragm in the make-up valve, and the lower surface of the diaphragm in the unloading valve. The counterbalancing steam force having been decreased, the individual valve springs will move the valve stem and plug upward in the make-up valve to open, and downward in the unloading valve to close.

The regulator valve glands should be kept just tight enough to prevent leakage. Periodically, the pipe plug in the side of the bonnets should be removed and the reservoir packed with graphite bearing lubricant to maintain smooth operation of the main valve rods. The valve is simple, positive, and does not require recalibration during service. For additional information consult the manufacturer's technical manual.

LIFTING TURBINE CASING AND GEAR CASING

The procedure to be followed in dismantling the turbine may be determined by studying the manufacturer's technical manual and the applicable blueprints. The instructions listed here are general rather than specific. However, most generator turbine casings may be lifted by using the following procedure:

1. Remove all piping to the throttle valve.
2. Remove the throttle valve.
3. Disconnect the restoring lever from the pilot valve and synchronizing devices.
4. Remove the insulation from the upper turbine casing.
5. Remove the bolts from the horizontal joint of the turbine casing. The bolts in the circumferential joint need not be removed.
6. Remove the upper havles of the high pressure and low pressure packing boxes. Remove the packing from the high and the low pressure packing boxes.
7. Attach the proper lifting gear, using the padeyes welded in the overhead and the eyebolts in the casing, and lift the casing. Jack screws may be used to help break the horizontal joint. In most installations, the upper halves of the diaphragms and the diaphragm packing are fastened to the upper half of the casing and will be lifted with it.
8. Use guide pins, minimum of two, preferably three.

If the turbine rotor is to be removed, the upper half of the reduction gear casing must be removed first. This can be accomplished as follows:

1. Remove the pilot valve body and the synchronizing device.
2. Remove the cover from the high speed thrust bearing, and the two studs that hold the thrust bearing to the upper half of the casing (if applicable).
3. Remove all gages and thermometers from the upper half of the casing.
4. Remove all parting flange bolts. Remove any end plates which may be bolted to the upper and lower halves of the gear casing.
5. Remove the bolts holding the oil deflector halves together (if applicable).
6. Remove all bolts that connect the upper and lower casing flanges. Then use the jacking bolts to break the joint. Failure to break the joint in this manner may distort the casing.
7. Lift the casing by means of the padeyes, eyebolts, and chain hoists provided for this purpose. Lift the casing straight up to avoid striking the gear.
8. Since the pilot valve remains connected to the governor, be sure to lift the casing high enough to clear the pilot valve.
9. Remove the upper halves of the journal bearings that support the turbine pinion rotor.
10. Remove the high speed thrust bearing.
11. Lift the turbine rotor and the pinion shaft as a single element.

PREVENTIVE MAINTENANCE

Turbogenerator units must be maintained and systematic inspections and tests at periodic intervals performed, in order to ensure safe and reliable operation.

At the required intervals, idle turbines should be run with steam (if available) or turned by hand. Oil should be circulated through the system by means of the hand pump. The trip mechanism and other working parts should be lubricated. The lubricating oil should be sampled, tested for the presence of water, and checked to determine its general condition; when necessary, the lubricating oil should be purified. All relief valves should be operated by hand at the required intervals, in order to make sure that they will operate when necessary.

At somewhat less frequent intervals (usually quarterly) the relief valves should be tested by steam (except on turbines that do not have exhaust stop valves). Also, the position of the rotor should be checked and the thrust bearing oil clearance measured.

SAFETY PRECAUTIONS

Safety precautions are extremely important and must be strictly adhered to for the safety of operating personnel and to prevent damage to the machine.

Operating instructions and safety precautions for turbogenerators should be posted in the vicinity of the units. The safety precautions listed in this chapter are the MINIMUM required. More complete information on safety precautions should be obtained from NAVSHIPS Technical Manual and the manufacturer's technical manual furnished with each unit.

1. Do not operate a turbogenerator that has an inoperative overspeed trip, back-pressure trip, or constant speed governor.
2. Keep all relief valves and the sentinel valve in good operating condition, and keep them set at the pressures specified by the manufacturers.
3. Test the exhaust casing relief valve by hand before admitting steam to the turbine. At least quarterly, test the exhaust casing relief valve by steam.
4. Keep the oil sump filled with clean oil at all times.
5. Avoid water hammer and damage to turbine blading and thrust bearings by properly draining steam lines and opening steam valves slowly.
6. Before putting a turbogenerator in service, test the overspeed trip.
7. Before starting a turbogenerator. check to see that it is clear of all foreign matter.
8. Do not pass steam through a turbine at rest, admit enough steam to immediately start the unit rolling.
9. Do not allow air to be drawn through the turbine glands when the rotor is at rest.
10. Keep the governor operating mechanism, valve stems, and other moving parts clean and free of corrosion.
11. Keep oil pressures at the values specified by the manufacturer.
12. Examine and clean the lube oil strainers at least once each four hours of operation and more often if operating conditions indicate the need for more frequent cleaning. Always ensure that the strainer caps are properly secured prior to use.
13. Do not admit any steam (exhaust or drains) to the auxiliary condenser before an adequate flow of cooling water is passing through the condenser tubes.
14. Do not admit steam to the auxiliary air ejectors before the auxiliary condensate pump is started.
15. Never operate a turbogenerator that is known to have defective safety devices, defective control devices, or excessive journal or thrust bearing clearances.
16. Frequently inspect all firemain and cooling water lines in the vicinity of the generator for leaks.

CHAPTER 5

HEAT EXCHANGERS AND AIR EJECTORS

As a Machinist's Mate 1 or Machinist's Mate C you should be familiar with maintenance of heat exchangers and air ejectors installed on Navy ships. Information concerning construction and operation of these units may be found in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D and in *NAVSHIPS Technical Manual*.

Most of the information given in this chapter concerns maintenance and repair of main and auxiliary condensers, deaerating feed tanks, and lube oil coolers. Since you are required to know how to maintain air ejectors, information on repairing, testing, and maintaining air ejectors is also included in this chapter.

MAINTENANCE OF MAIN AND AUXILIARY CONDENSERS

Although shipyard, repair ship, or tender personnel are usually responsible for such repair work as retubing condensers and overhauling injection and overboard valves, you should have a good understanding of the procedures involved and should be qualified to act as a ship's inspector to see that all work is being performed satisfactorily. Machinist's Mates will be involved in inspecting and cleaning main and auxiliary condensers, checking for leaks, plugging tubes, and operating the units.

INSPECTING AND CLEANING CONDENSERS

Under normal operating conditions, the salt water side of a main condenser should be ...cted once each month or immediately after ...xtended cruise. The steam side of a main condenser should be inspected each quarter when the inspection covers are removed from the low pressure turbines.

Conditions may arise which will necessitate more frequent inspections of main condensers. The ship may operate in shallow water, or may operate in waters where there are large amounts of seaweed, schools of small fish, or large amounts of oil. When any of these conditions occur, the condenser should be opened for inspection and cleaning.

The sea water sides of condensers must be carefully maintained to prevent failures due to deposits on tubes and also to prevent loss of heat transfer due to accumulations of these deposits. The sea water sides of condensers must be inspected and cleaned at the following times:

1. Once each month if permitted by ship's operations.
2. At any time the condenser is opened for inspection or the replacement of zincs (when installed).
3. During drydocking or at any other time the salt water side of the condenser is drained.
4. Before initial sea trials and before full power trials.
5. After an extended cruise.

Before opening the salt water side of a condenser, read and observe all precautions listed in this chapter and in chapter 9460 of *NAVSHIPS Technical Manual*.

Some of the more important condenser parts which require periodic inspection and cleaning are zincs (when installed), tubes, and steam sides.

Zincs

Where zinc anodes are required to protect the condenser materials from electrolysis, good metallic contact must exist between the anodes and the metal of the condenser.

A casual inspection of a badly scaled zinc anode, especially while it is still wet, may lead personnel to believe that the metal instead of scale is exposed. The anode, even though it appears to be in good condition, should be tested with a chipping hammer to learn the true condition of the metal. Whenever zincs are inspected or cleaned, the condition of the metallic contact between the anode and its support should be checked. For information on applicable policy refer to chapter 14, *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

Tubes

Deposits which lodge within a condenser tube are likely to cause failure of the tube, unless promptly removed. Particles of mud, sand, or other foreign matter which lodge in the tube cause corrosion pits to start under the particles. Once a pit is started, it will widen and deepen, even though the foreign matter is removed. Larger particles or such foreign matter as stones, shells, metal, and wood, will result in the formation of corrosion pits where the foreign matter touches the tube surface, and will cause an increase in velocity of the sea water (flowing past the obstruction) which will result in breaking down the protective film on the tube.

The resistance of condenser tubes to corrosion depends on a thin, adherent, continuous film of corrosion products on the surface exposed to sea water; therefore, extreme care must be taken when cleaning the tubes not to use abrasive tools capable of marring or scratching the surface of the tube. Wire brushes or rubber plugs having metal parts should never be used inside condenser tubes. Any scratch or perforation of the corrosion-resisting film will form a pit which will widen and deepen and eventually result in tube failure (through corrosion pitting), in the same manner as occurs when foreign matter lodges on the tube surface. Any cleaning equipment must be carefully used to avoid damaging the protective film, which will cause tube failures.

For ordinary cleaning, an air lance should be pushed through each tube, the tube sheets should be washed clean, and all foreign matter should be removed from the water chests. In installations where there is severe fouling, a water lance should be pushed through each tube to remove foreign matter. Where there is extreme fouling, a rotating bristle brush should be run through each tube—or soft rubber plugs, available at shipyards, may be driven through the tubes by use of air or water pressure – then this procedure should be followed by water lancing.

Steam Side

Whenever the manhole plates are removed from the low pressure turbine for inspection or maintenance, the steam side of the tubes should be inspected. The entire steam side should be checked for grease and dirt. If grease and dirt are found, they can be removed by boiling out the condenser, using a solution of trisodium phosphate. Normally, condensers which serve turbines should not require boiling out more frequently then every shipyard overhaul period. Instructions for the boiling out process may be found in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D, and in chapter 9460 of *NAVSHIPS Technical Manual*.

TUBE LEAKAGE

Any tube leakage, however slight, will cause serious damage if neglected. The condensate system will become contaminated and this will result in serious damage to the boiler tubes. It is not unusual for a newly tubed condenser to develop leaks due to defective tubes or tube sheets, or to improper installation. However, if the defects are corrected, the condenser will give years of satisfactory service.

The most common cause of tube leakage is deterioration which starts at the sea water side of the tube and proceeds through the tube wall to the steam side. However, leakage may also be caused by deterioration starting at the fresh water side of the tube wall, by a defective joint between the tube and tube sheet, or by cracking of the tube wall or tube sheet.

Impingement Erosion

Sea water flowing into the condenser tubes at high velocity tends to remove the thin protective film of corrosion products adhering to the tube walls. This protective film is replaced at the expense of further corrosion of the tube wall. As the protective film is continually removed and is replaced by corrosion products, the tube wall is gradually thinned and the joint between the tube and the tube sheet is weakened, so that a salt water leak utlimately occurs, through the failure of the tube joint or perforation of the tube wall beyond the tube sheet. This type of attack is generally confined to the region of the tube at or near the inlet end and is known as impingement erosion, inlet end attack, or bubble attack. The occurrence and rapidity of the attack is influenced mainly by water velocity through the tubes. It is also influenced by the amount of air entrained with the circulating water, and by the design of water chests and injection piping.

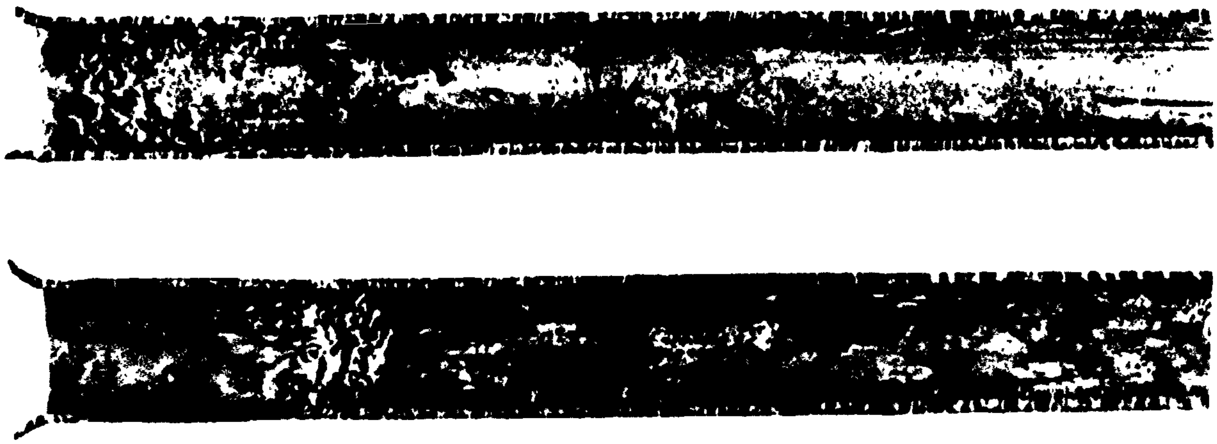
Tube deterioration resulting from impingement erosion of the tube ends can be minimized by proper regulation of circulating water through condensers and by proper venting of water chests.

Figure 5-1 shows a tube which has been badly damaged at the inlet end by impingement erosion.

If wet steam is permitted to impinge on condenser tubes at high velocity, the surface of the tubes will rapidly erode and this erosion will eventually result in perforation of the tube wall and leakage of sea water into the condensate. Baffles or distribution pipes are installed within the condenser shell to prevent direct impingement of water and steam from the auxiliary exhaust line, the recirculating line, and the makeup feed line.

These baffles must be installed in such a way that they do not touch the tubes, since vibration will cause tube failure. If frequent tube leaks occur in the vicinity of a steam or water connection to the condenser shell, it is evidence that the baffling system is defective or that the plant is not being operated properly.

In order to prevent tube erosion from auxiliary exhaust lines, it is essential that the line be continously and throughly drained. Before you shift the auxiliary exhaust to a condenser, all drain valves on the exhaust line should be opened and every precaution taken to ensure that the exhaust line is drained properly. If there is a pocket in the exhaust line which will allow condensate to collect, a drain should be installed to ensure complete drainage of the auxiliary exhaust line.



96.26

Figure 5-1.—Tube damaged by impingement erosion.

Testing for Leaks

Several methods of testing condensers for leaks are described in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D. A review of one method of testing follows:

1. Drain the salt water side of the condenser and remove the water box inspection plates. This includes the small inspection plates at the top of the water boxes.
2. Place the steam side of the condenser under air pressure not to exceed 15 psig.
3. Slowly fill the salt water side of the condenser. Replace the inspection plates as the water level nears the openings.
4. Carefully observe the surface of the water near both tube sheets. Air bubbles indicate leakage.
5. A large leak will be noticed immediately. Detecting smaller leakage, especially leakage from a tube, will require more time and closer observation. Trim or list of the ship should be noted, and a close watch should be maintained on the high side of the tubes. If tubes are bowed, this should be taken into consideration when inspecting for leaks.

Salt water leaks into the condensate system cannot always be detected by the use of salinity indicators alone. The first indication of a salt water leak may be a chloride buildup in the boiler.

If leaky tubes are found, they must be plugged so that the condenser can be kept in service. Plugs, which are furnished by the manufacturer, should be driven into the tube ends with light hammer blows. If it becomes necessary to plug tube sheet holes after a tube has been removed, a short section of tube should be expanded into the tube hole before the tube plug is inserted, this will protect the tube holes from damage.

Plugged tubes should be renewed during the next shipyard availability if the water chests are removed for other work: or if more than 10 percent of the tubes are plugged, a retubing request should be submitted, via the type commander, to NAVSEA.

RETUBING CONDENSERS

Under normal conditions, an MM1 or MMC will not be expected to retube a condenser. Because of modern materials and manufacturing methods, condensers seldom need retubing. When they do, special tools and equipment are necessary, and the work is performed by tenders, repair ships, or a shipyard. The MM1 or MMC does have the responsibility of inspecting the job to see that it has been properly completed and tested.

In general, specimen tubes should not be drawn from a condenser or heat exchanger, for examination purposes, except when removal is specifically directed by NAVSEA, or by a Board of Inspection and Survey. However, under the following conditions, tubes MAY be drawn without NAVSEA authorization:

1. When frequent leaks have been caused by tube failures, specimen tubes should be drawn from widely separated parts of the unit in order to establish the general condition of the tubes.

2. When several tubes have failed in the vicinity of a steam or water inlet to the condenser shell, specimen tubes should be drawn unless the cause of the failure can be determined by visual inspection of the steam side of the unit.

Samples from the most badly deteriorated tubes should be carefully marked to show the top and the bottom of each sample, and the location from which the sample was drawn. The samples should be cut into lengths of about 12 inches, identified as to position along the length of the tube, split lengthwise, and opened to permit ready examination. These samples are then forwarded to NAVSEA, together with a complete report of the conditions found.

Retubing Request

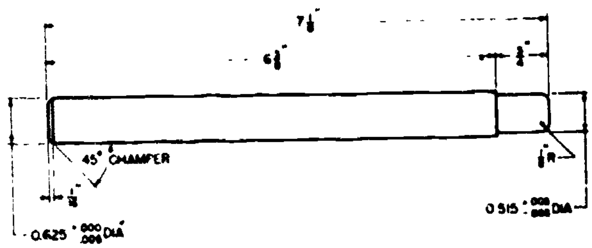
Before any work is begun in retubing a main condenser, authorization must be obtained from NAVSEA. When a retubing request is submitted, the following information must accompany the request:

1. The condenser involved and the date when the condenser was last tubed or retubed.
2. Whether or not any of the tube leaks were caused by improperly expanded or packed tube joints.
3. The date when each leak occurred, the type of tube failure (usually determined when the failed tube is drawn and split for inspection), the conditions of operation, and any known or suspected contributory causes.
4. The source of supply of the tube, if known.
5. The position in the tube bundle of each failed tube and of each specimen tube drawn for inspection.
6. The part(s) of each specimen tube where defects were found (external, internal, top, bottom, ends, etc.); to meet this requirement, tube ends must be marked before removal so that the top can be located.
7. The tube, tube sheet, and water box materials, and the type of tube joints employed.
8. The condition of the zincs; the frequency of renewal, the frequency of scaling, and the method of cleaning the zincs (when installed).
9. The method and frequency of cleaning the tubes.
10. Whether or not the unit was kept thoroughly vented during its operation.
11. Whether or not the tubes were cleaned and blown out whenever sea water was drained from the unit.
12. If severe deterioration of tube ends and tube sheets is visible and photographic equipment is available, photographs of the tube sheets should be taken and sent to NAVSEA for information purposes.
13. The extent of work considered necessary. Partial retubing of a condenser is not considered economical, except that authorization is sometimes given for retubing one pass of a two-pass condenser.
14. A list of materials required, specifying length, outside diameter, wall thickness, and type of tube joints at both inlet and outlet ends.
15. Recommendations and comments by authority endorsing the request.

Retubing of auxiliary condensers and other small heat exchangers may be accomplished by forces afloat or by a shipyard without obtaining authorization from NAVSEA. Only the type commander need approve this type of retubing. Complete reports of such retubing must be forwarded to NAVSEA and are to include the same information that is required for requests for retubing main condensers.

Removing Tubes

When a main condenser is to be retubed, the most efficient way of removing the old tubes is to cut them inside the shell by use of a power-driven saw, or other suitable cutting tool and then drive the ends of the tubes out of the tube sheets with a drift. Figure 5-2 shows a drift suitable for tubes which have a 5/8-inch outside diameter and a wall thickness of 0.049 inch. If serious difficulty is encountered in removing expanded tubes, it may be necessary to ream the expanded ends so that only a thin shell remains at the outer surface of the tube.



98.34

Figure 5-2.—Drift for driving tube ends from tube sheets.

If a reamer is used, it should be provided with a pilot which closely fits the inside bore of the tube, and extreme care must be taken to ensure that the reamer does not touch or mar the surfaces of the tube holes in the tube sheet. Figure 5-3 shows a reamer suitable for this type of work.

Regardless of the method used to remove the tubes, the tube holes in the tube sheets must not be damaged in any way.

Renewing Tubes

Before installing replacement tubes, a very careful examination of the interior parts of the condenser shell must be conducted. If there is

98.35

Figure 5-3.—Reamer for removing expanded tube ends.

any reason to believe that the joints between the tube sheets and the condenser shell are not in perfect condition, the tube sheets should be removed, the flanges trued, and new gaskets installed. Joints between the stay-rods and the tube sheets should be remade and the stay-rods repacked. Should any defects be found after the new tubes are installed, it may be necessary to cut out the newly installed tubes to correct the defect(s).

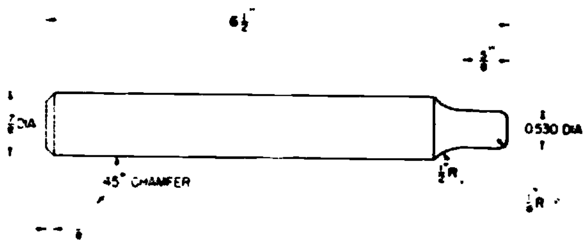
Only copper-nickel tubes conforming to NAVSEA specifications are to be used in condensers that are salt-water cooled. These tubes are furnished in stock lengths and must be cut to proper length by the installing activity. The usual practice is to cut the tubes in lengths about 1/8 inch longer than the distance between the outside faces of the tube sheets. After installation, the tubes are finished to the exact length, by using an air-driven end mill or surface grinder.

EXPANDING TUBES.—Nearly all condensers installed aboard naval ships have the inlet tube ends expanded in the tube sheet, forming a metal-to-metal joint. In many installations, the oulet tube ends are also expanded. If the condenser tubes are expanded at both ends, it is common practice to provide one or more grooves, or serrations, in the tube holes in order to increase the holding power of the expanded tube joint. Such grooves should be thoroughly cleaned out and any burrs removed prior to the installation of new tubes.

Tube expanders used in retubing condensers and other heat exchangers must meet Navy specifications. No type of tube expander should be used by forces afloat or shipyards, except the expanders furnished to the ship by the manufacturer and approved by NAVSEA. The tube expander rolls should be tapered to correspond with the taper of the expander mandrel to ensure parallel expansion of the tube walls. The inner ends of the rolls should be suitably rounded off to form a torpedo-shaped end in order to prevent ridging and cutting of the tubes at the inner end of the expanded joint. In order for a tube expander to be properly set for a given job, it is generally necessary that the overall length of the rolls be not less than 3/16 inch greater, and not more than 5/8 inch greater than the thickness of the tube sheet into which the tube is expanded. The expander should be adjusted so that the expanded portion of the tube does not extend completely through the cylindrical portion of the tube sheet hole; about 1/8 inch of the tube at the inner end of the tube hold is left unexpanded. If the tubes are expanded completely through the tube sheet, the part of the expanded joint which extends into the condenser and beyond the support of the tube hole, will bulge and the subsequent removal of tubes will be extremely difficult.

After the tubes are expanded, the inlet ends of the tubes should be belled or flared to an outside diameter of not more than 3/4 inch for 5/8-inch OD (outside diameter) tubes, and not more than 7/8 inch for 3/4-inch OD tubes.

Flaring tools must not be driven into the tube end so hard that the wall of the tube is appreciably thinned or cut. Figure 5-4 shows a flaring tool that is suitable for 5/8-inch OD tubes which have a wall thickness of 0.049 inch.



98.36

Figure 5-4.—Tool for flaring main condenser tubes.

It is good practice to mill or grind the projecting flared ends of the newly installed tubes flush with the tube sheet surface in order to provide a smooth entrance for the circulating water flowing into the inlet ends of the tubes. It is not necessary to flare the outlet ends of the tubes;

the tube outlet ends may be allowed to project 1/16 inch from the face of the tube sheet surface.

PACKING TUBES. Flexible metallic packing in accordance with Navy specifications, should be used to pack the outlet ends of packed condenser tubes. The inlet ends of the tubes should be expanded into the tube sheets before the outlet ends are packed. The old packing must be completely removed and the threads and serrations of the glands thoroughly cleaned of all foreign matter.

When stuffing box glands are 3/4 inch deep, the proper packing consists of two fiber rings and two metallic rings. To facilitate the installation of packing, a loading pin (fig. 5-5) should be inserted into the outlet ends of the tubes.

After the loading pin is inserted, a fiber packing ring is placed on the pin and driven to the bottom of the stuffing box. Next, a metallic packing ring is placed on the loading pin and calked into the packing box with three or four light hammer blows, to cause the metal to flow into the threads of the gland. Then these operations are repeated, another fiber ring and another metallic ring are inserted in the same manner; each ring is calked in place separately. If the depth of the stuffing box is greater than 3/4 inch, an additional metallic ring should be installed and calked into place in order to completely fill the stuffing box with packing.

If the stuffing box is 5/8 inch deep instead of 3/4 inch deep, only three rings of packing can be used, one metallic ring is calked in place, followed by a fiber ring and a second metallic ring. The outlet ends of packed condenser tubes are never flared, expanded, or belled.

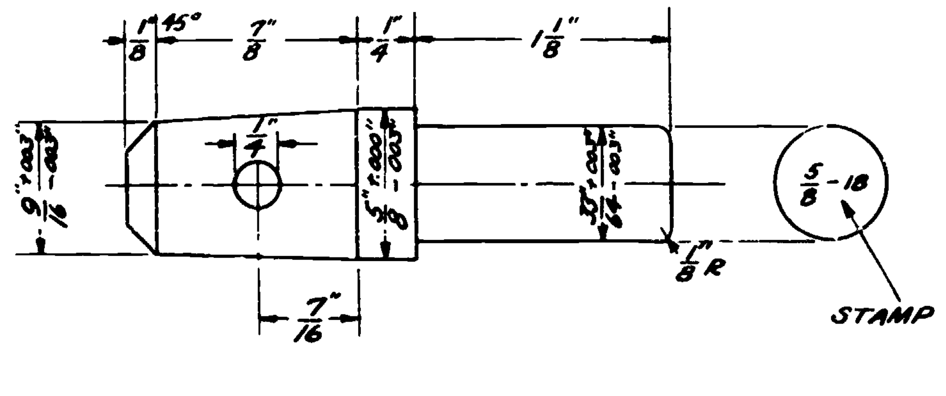
When a condenser is retubed, the tubes should be tested for leaks. The test is made by filling the shell with warm water. (Warm water must be used to avoid condensate forming on tubes and tube sheets and giving a false indication of leaking.) If any leaky tubes are found, they can be recalked with light hammer blows applied to the calking tool.

The amount of force used in striking the calking tool with the hammer is extremely important. If too little force is used, the joint will leak. If too much force is used, it will "neck" the tube end so that the tube end will be held too tightly in the packing gland to allow proper movement during normal expansion. When the necked tube does move through the packing, leakage at the joint will result.

CARE OF IDLE CONDENSERS

Most condensers on naval ships have condenser tubes either expanded at both ends, or expanded at the inlet end and packed at the outlet end. These units should normally be drained and kept empty when secured. However, if the condenser is to be used within a few days, it may be completely filled with water (which should be circulated daily) unless the ship is lying in highly polluted water. When in polluted water, the condenser should be drained and thoroughly washed out whenever it is secured.

Whenever the sea water side of a condenser is drained, special care should be taken to ensure that the tubes do not have water anywhere along



96.27

Figure 5-5.—Loading pin for packing main condenser tubes.

their lengths. Tubes frequently become sagged and water trapped in these pockets at one or more points along the tube length, if allowed to remain in a drained condenser, will gradually evaporate. The impurities left behind (after the water has evaporated) will corrode the tubes at these points, and in time will result in tube failure. This action is particularly acute when condensers are drained of highly polluted water. The best method of avoiding this type of tube deterioration, when an ample supply of fresh water is available from a pier, is to water-lance each tube with fresh water in order to wash out the polluted water and remove foreign matter from the tubes. Following the water-lancing operation, the tubes should be air-lanced and left dry until the condenser is again put in service.

If sufficient fresh water is not available for water-lancing, each condenser tube should be air-lanced and left completely dry; then the condenser should be inspected daily. If any water tends to collect in the tubes, through condensation from the atmosphere, the air-lancing operation should be repeated, as necessary, to avoid the formation of water pockets at low points along the tubes.

When a condenser is secured, the steam side should be kept empty.

SAFETY PRECAUTIONS FOR CONDENSERS

When opening a main condenser for cleaning or inspection, or when testing a main condenser, there are several safety precautions that must be observed. The following procedures and precautions, when carried out properly, will help prevent casualties to personnel and machinery:

1. Before the salt water side of a condenser is opened, all sea connections including the main injection valve, circulating pump suction valve, and main overboard valve, are to be closed tightly and secured against accidental opening. This is necessary to avoid the possibility of flooding an engineroom. Safety gates, where provided, are to be installed.

2. On condensers having electrically operated injection and overboard valves, the electrical circuits serving these motors are to be opened and tagged to prevent accidentally energizing these circuits.

3. Before a manhole or handhole plate is removed, drain the salt water side of the condenser by using the drain valve provided in the inlet water box. This is done to make sure that all sea connections are tightly closed.

4. If practicable, inspection plates are to be replaced and secured before work is discontinued each day.

5. Never subject condensers to a test pressure in excess of 15 psig.

6. When testing for leaks, do not stop because one leak is found. The entire surface of both tube sheets must be checked, as other leaks may exist. Determine whether each leak is in the tube joint or in the tube wall, so that the proper repairs can be made.

7. There is always a possibility that hydrogen or other gases may be present in the steam side or the salt water side of a condenser. No open flame or tool which might cause a spark should be brought close to a newly opened condenser. Personnel are not to be permitted to enter a newly opened condenser until it has been thoroughly blown out with steam or air.

8. The salt water side of a condenser must be drained before flooding of the steam side, and must be kept drained until the steam side is emptied.

9. The relief valve (set at 15 psig) mounted on the inlet water chest is to be lifted by hand whenever condensers are secured.

10. If a loss of vacuum is accompanied by a hot or flooded condenser, the units exhausting into the condenser must be slowed or stopped until the casualty is corrected. Condensate must not be allowed to collect in condensers and overflow into the turbines or engines.

11. Condenser shell relief valves are to be lifted by hand before a condenser is put into service.

12. No permanent connection which could subject the salt water side to a pressure in excess of 15 psig, is to be retained between any condenser and a water system.

13. No permanent connection which could allow salt water to enter the steam side of the condenser is to be retained.

14. Test the main circulating pump bilge suction, when so directed by the engineer officer. To conduct this test, it is generally necessary only to start the main circulating pump, open the bilge suction line stop or check valve, and then close down on the sea suction line valve to about 3/4 closed, or until the maximum bilge suction capacity is obtained.

OPERATION OF CONDENSERS

Compared with the number of casualties that occur to some units of naval machinery, relatively few casualties occur to main condensers. The most frequent casualty to a main condenser is a reduction in vacuum. Inadequate vacuum or any other casualty to a main condenser will result in failure of the propulsion turbines to produce full power or in complete failure of the main engines. Condensers should be operated to obtain a vacuum in accordance with design requirements and to obtain maximum service life and reliability of the equipment.

VACUUM REGULATION

Under normal operating conditions, condensers fitted with scoop injection should be operated to maintain the maximum vacuum obtainable and with the main injection and overboard valves wide open, except under the following conditions.

When making FULL POWER or speeds closely approaching full power, under cold injection conditions, the condenser will usually be capable of obtaining a higher vacuum than can be effectively used by the low pressure turbine. In the average installation, as the FULL POWER vacuum becomes higher than about one inch of mercury above the vacuum for which the low pressure turbine was designed, the extra steam that is required to heat the condensate will outweigh the added economy of turbine operation that is gained by the higher vacuum. The designed full power vacuum for any turbine installation may be obtained from the manufacturer's technical manual.

Prior to 1950, most turbines served by scoop injected condensers were designed for a full power exhaust vacuum of about 27 1/2 inches mercury (1 1/4 psi absolute) with a circulating water injection temperature of 75° F. If the injection temperature becomes low enough so that the full power vacuum tends to increase about 28 1/2 inches mercury, improved overall plant economy may be secured by throttling the flow of circulating water as necessary to limit the vacuum of 28 1/2 inches mercury. In later vessels, the turbines served by scoop injected condensers were designed for a full power exhaust vacuum of 25 inches mercury (2.45 psi absolute) with a circulating water injection temperature of 75°F in order to take advantage of the decreased size, space, and weight of the main condensers designed for lower vacuum. In this case the vacuum with low injection temperature should be limited to approximately 26 inches mercury.

When operating at cruising speeds, the turbines can generally make effective use of the maximum vacuum of which the condensing plant is capable. However, with cold injection at low power, the condenser becomes capable of producing a vacuum higher than that at which the air removal equipment will handle the normal air leakage into the system. Under standby conditions with very little steam discharged to the condenser, most installations fitted with properly functioning air ejectors will produce a maximum vacuum of about 29 1/2 inches mercury with cold injection temperature. Under these conditions, the average installation fitted with air pumps operated at normal speed will produce a maximum vacuum of 28 to 29 inches mercury depending on whether or not augmenters are fitted. When cruising at low and medium powers with cold injection, as the condenser vacuum tends to approach the maximum of which the system is capable under standby conditions with that injection temperature, the air removal equipment tends to become unable to free the condenser of normal air leakage. The air collects in the condenser, tending to insulate the tubes from the condensating steam, and to settle into the hot well, and there is usually a noticeable increase in the condensate depression. To avoid loss of economy and absorption of air into the condensate under these conditions, it is good practice to throttle the flow of circulating water as necessary to limit the vacuum to about 0.2 inch mercury less than the maximum obtainable with full flow of circulating water, or as necessary to reduce the condensate depression to normal. If the condensate depression remains between zero to about two degrees under low power operation at medium injection temperature, it may be assumed that the air removal equipment is ridding the condenser of air leakage, and throttling of circulating water is unnecessary.

CIRCULATING WATER CONTROL

When the gate valve in the circulating water overboard piping is used to regulate the water flow through the condenser, this valve should be kept at least 1/4 open. If a gate valve used for throttling is closed more than 3/4, the gate is likely to pound against the seat rings and damage the valve so that it will not be watertight when closed. Some erosion of the valve gate and seating rings may take place if the valve is continually used for throttling. Whenever a ship is drydocked, a careful inspection of injection and overboard valves should be made in order that the valves may be kept in good working condition and watertight.

If, while an overboard valve is throttled, a sudden increase in power is needed, a slight loss in vacuum will occur but the loss will not usually be serious and can be corrected by opening the overboard valve. In the event of an unexpected demand for full power astern, the overboard valve should be opened wide as quickly as possible.

LOSS OF VACUUM

When a loss of vacuum occurs in a condenser, it means that the units of machinery exhausting into the condenser are out of commission. Maintaining proper vacuum is one of the more important duties of engineroom watchstanders. This training manual cannot cover all of the reasons for loss of vacuum however, since air leakage into the vacuum system is the most common cause of vacuum loss, some of the methods of conducting air tests are as follows:

AIR LEAKAGE into a condenser decreases the vacuum obtainable and increases the condensate depression. If air leakage becomes excessive, the units of machinery exhausting to the condenser will have to be secured.

There are many ways in which air can leak into a system under vacuum. Every FLANGE, GASKET, CONNECTION, PACKING GLAND and VALVE BONNET that connects to the vacuum system can be a source of air leaking into the condenser. Air leaks can be very difficult to locate; they can be searched for in various ways. One method is by filling the condenser and the connected piping which is normally under vacuum, with fresh water—then using compressed air, to build up a pressure of 5 to 10 psig in the turbine casing and checking the condenser and piping for water leaks. A water leak indicates an air leak.

Another method of locating an air leak is by making the CANDLE FLAME TEST. With the system under vacuum, hold a lighted candle to all areas where leaks are suspected. If the candle flame is held close to a leak, the vacuum will draw the flame toward the leak.

A more reliable method of searching for leaks is to apply SOAPSUDS to areas where leaks are suspected. The soapsuds solution should be prepared so that it has the consistency of liquid hand soap and will work up lather on a brush. With the condenser shell subjected to a five-pound air pressure, apply the lather all the way around the joints, then the joints should be carefully checked for bubbles. Doubtful spots should be lathered a second time, and if you are still in doubt about the existence of leaks, doubtful spots should be lathered several times.

Another method of testing a vacuum system for leaks is by using the AIR TEST. If the test is to be conducted on a main condenser, the procedure is as follows:

Start a lube oil service pump; engage and start the turning gear. Cut in gland sealing steam to the main turbines. Next, build up a pressure of 5 to 10 psig throughout the vacuum system. Listen carefully for air leaking out of the system. This method is more effective if all the vents and machinery in the engineroom, except the lube oil pump and turning gear, can be secured, since this method depends entirely on detecting the sound of air escaping.

When testing for air leaks, all places where it is possible for an air leak to exist must be investigated. Condensers have many fittings and joints which should be examined as far back in the lines as vacuum exists under any operating conditions.

Leaks at flanged joints and in porous castings can usually be stopped with an application of shellac when the condenser is under vacuum. If shellac is used, this should be considered a temporary repair–and permanent repairs should be made as soon as time and the ship's operation permit.

Main exhaust trunk flanges are generally fitted with a flange grooving system, in installations where the condenser supports the turbine, to provide for pressure pumping with a suitable sealing compound. If the shell relief valve (or its connection to the condenser shell) is suspected of leaking, it can, in most installations, be tested in place. Most shell relief valves are fitted with a small gage glass to permit introduction of water above the disk as a test for tightness.

OTHER HEAT EXCHANGERS

Condensers are but one type of heat exchanger found in enginerooms. Lube oil coolers, air coolers, and deaerating feed tanks are other heat exchangers that Machinist's Mates are responsible for maintaining. In the following sections, information will be given on maintaining these units.

DEAERATING FEED TANKS

Machinist's Mates should be familiar with the operation and maintenance of deaerating feed tanks. Information on principles of operation of deaerating feed tanks may be found in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D, and in chapter 9562 of *NAVSHIPS Technical Manual*

This chapter contains general information on operation and maintenance of these units. For details on any specific unit, check the manufacturer's technical manual.

Operating a Deaerating Feed Tank

During normal operation, the only control necessary is maintaining the proper water level. This is done with automatic water level control valves. (On some of the older ships, this is done with manual water level control valves.) If the water level is too high, the tank cannot properly remove the air and noncondensable gases from the feed water. A low water level may endanger the main feed booster pumps, the main feed pumps, and the boilers.

Deaerating feed tanks remove gases from the feed water by using the principle that the solubility of gases in feed water approaches zero when the water temperature approaches the boiling point. During operation, steam and water are mixed by spraying the water so that it comes in contact with steam from the auxiliary exhaust line. The quantity of steam must always be proportional to the quantity of water, otherwise, faulty operation or a casualty will result.

Overfilling the deaerating tank may upset the steam-water balance and cool the water to such an extent that ineffective deaeration will take place. Overfilling the deaerating tank also wastes heat and fuel. The excess water, which will have to run down to the condenser, will be cooled–and when it reenters the deaerating tank, more steam will be required to reheat it. If an excessive amount of cold water enters the deaerating feed tank, the temperature drop in the tank will cause a corresponding drop in pressure. As the deaerating feed tank pressure drops, more auxiliary exhaust steam enters the tank. This reduces the auxiliary exhaust line pressure, which causes the augmenting valve (150 psi line to auxiliary exhaust line) to open and bleed live steam into the deaerating feed tank.

When an excessive amount of cold water suddenly enters the deaerating feed tank, a serious casualty may result. The large amount of cold water will cool (quench) the upper area of the deaerating feed tank and condense the steam so fast that the pressure is reduced throughout the deaerating feed tank. This permits the hot condensate in the lower portion of the deaerating feed tank and feed booster pump to boil or flash into vapor causing the booster pump to lose suction until the pressure is restored and the boiling of the condensate ceases. With a loss of feed booster pump pressure, the main feed pump suction is reduced or lost entirely, causing serious damage to the feed pump and loss of feed water supply to the boiler(s). Some ships have safety devices installed on the main feed pumps which will stop the main feed pump when a partial or total loss of main feed booster pressure occurs.

The mixture of condensate, drains, and make-up feed water, constituting the inlet water to the deaerating tank, enters through the tubes of the vent condenser. The condensate pump discharge pressure forces the water through the spray valves of the spray head and discharges it in a fine spray throughout the steam filled top or preheater section of the deaerating feed tank.

If a spray nozzle sticks open, or if a spray nozzle spring is broken, the flow from the nozzle will not be in the form of a spray and the result will be ineffective deaeration. This condition cannot be discovered except by analysis of the feed water leaving the deaerating feed tank, or by inspecting the spray nozzles.

Inspection of the spray nozzles should be scheduled at frequent intervals.

In most deaerating feed tanks, the manhole provides access for the inspection of spray nozzles; other tanks are so designed that the spray nozzle chamber and the vent condenser must be removed in order to inspect the nozzles.

Complete information on constructing and using a test rig for spray valves can be found in chapter 9562 of *NAVSHIPS Technical Manual.*

OIL COOLERS

Oil coolers should be operated as required to maintain the oil (inlet) temperature to the bearings at the designed value. With the bearing orifices properly adjusted and the bearings in proper operating condition, a temperature of 120° F to 130° F on the discharge side of the cooler should satisfactorily meet all normal operating conditions.

When the system has more than one cooler, the coolers should be used alternately, and for approximately the same number of hours.

Maintenance of Lube Oil Coolers

With reasonable care lube oil coolers installed on Navy ships will remain in service for several years. When salt water is used as the cooling medium, failure is usually caused by erosion due to high water velocity or by corrosion due to electrolytic action.

All coolers are built in accordance with NAVSEA specifications. These specifications are designed to give adequate cooling with sea water velocities well below that which will cause appreciable erosion.

Reports of failure of this type of equipment are rare in comparison with the number of coolers installed in naval ships. Most cooler failures have occurred to units that are supplied with cooling water from a service main, with the supply of sea water available to the cooler limited only by a valve or an orifice in the cooler supply line. Under these conditions, too wide an opening of the valve, too large an orifice, or too high a pressure in the service main will cause excessive velocity through the cooler and consequent failure due to erosion. At the same time the oil temperature is usually not appreciably lower than that obtained with proper sea-water flow.

Of the two causes of cooler failure, the more likely one is erosion from high velocity sea water. To get satisfactory service from these units, the following precautions must be observed:

1. Limit the sea water flow to the minimum that is consistent with maintaining the oil temperature within limits specified by NAVSEA or as given in the manufacturer's technical manual.

2. When securing a cooler for any extended period, drain the salt-water side and flush with fresh water, when practicable. At all other times the cooler should be kept flooded and should be periodically flushed with salt water.

3. Clean in a manner prescribed by NAVSEA.

All the above precautions also apply to other heat transfer equipment such as refrigeration condensers, air compressor inter and after coolers, and other coolers that use sea water as a cooling medium.

Cleaning Lube Oil Coolers

If a lubricating system should become contaminated with salt water, the system must be thoroughly cleaned before it is put back into service. The cooler must be disassembled and all traces of rust, scale, and other foreign matter removed; otherwise serious damage will result.

All foreign matter in shell and tube coolers must be removed, prior to reassembly, from the inside of the shell and baffles. Removal should be done with scrapers and/or wire brushes.

With proper use of lubricating oil purifiers, filters, and strainers, it will usually be necessary to clean only the salt water sides of the shell and tube type coolers. This cleaning should be accomplished by air-lancing or water-lancing, and if necessary, with a round, bristle brush. Under no circumstances should a WIRE BRUSH be used for this purpose.

Removed tube bundles can be cleaned, when necessary, by flushing them with hot water. However, no attempt at chemical cleaning of shell and tube type coolers should be made without the specific approval of NAVSEA.

AIR COOLERS

Air coolers are used for closed circuit cooling of machinery. In this type of cooler, the air is circulated over and over again. The advantages of closed circuit cooling over open circuit cooling, where the atmospheric air is passed through the machine, include:

1. A cleaner machine, protected from any harmful gases or moisture which may be present in the outside air.

2. Low fire risks, as the oxygen content of the enclosed air is insufficient to sustain combustion. With open circuit cooling, in case of fire, the continuous entry of fresh air will supply additional oxygen to replace that which is consumed, whereas, with the closed system, once the available oxygen is consumed, combustion will cease for lack of oxygen.

3. Cooling of the machine is independent of outside air.

Maintenance of Air Coolers

The air cooler (fig. 5-6) is a double-tube type of cooler. The double-tube construction enables leaks in the water tubes to be detected before serious tube failure occurs.

Each double-tube consists of a water carrying tube surrounded by a close fitting outer tube. Axial grooves in the inside surface of the outer tube extend the full length of the cooler. The grooves in the tubes all open into TELL-TALE chambers at each end of the cooler. If a leak occurs in one of the main water carrying tubes, the leakage runs into the grooves in the surrounding tube, and from there it runs into one of the TELL-TALE chambers. This arrangement is designed to prevent water leakage into the air ducts of the machine. Leakage can be detected only by observing whether there is any discharge from the open ends of the TELL-TALE drain tubes.

To obtain continuous satisfactory service from the air coolers, it is necessary to operate and maintain such equipment properly. Inspections and preventive maintenance are invaluable in locating and preventing trouble before serious damage results.

Cleaning of Air Coolers

The air cooler must be cleaned whenever foreign matter interferes with the flow of air across the tubes or water deposits impair the flow of water through the tubes or whenever such accumulations either inside or outside the tubes prevent proper heat transfer. The cleaning of the cooler will be done at least every six months. To clean the air cooler, proceed as follows:

1. Close valves in water lines to and from air cooler. Drain water from cooler.
2. Disconnect water, vent, drain, and tell-tale connection.
3. Clean water passages as follows:
a. For ordinary cleaning, push an air lance through each tube, wash the tube sheets, and remove all foreign matter from water chests.
b. In case of more severe fouling, push a water lance instead of an air lance through each tube.

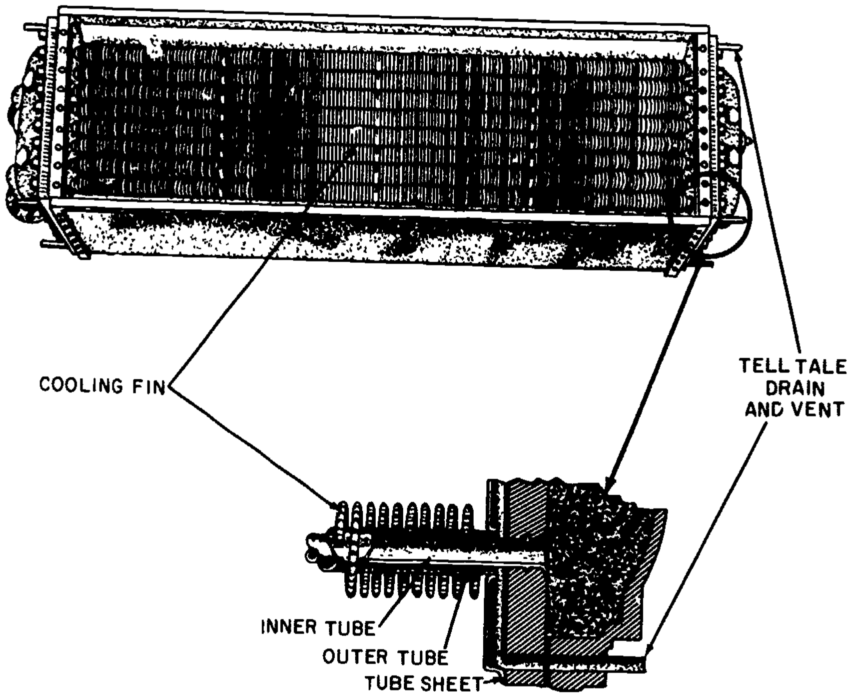


Figure 5-6.—Air cooler.

c. In cases of extreme fouling of tubes resulting from oil or grounding of a vessel, a rotating bristle brush may be run through each tube, or soft rubber plugs may be driven through the tubes by an air or water gun. Follow the bush by a water lance.

CAUTION: Never use abrasive tools which might scratch or mar the tube surface. (Any local scratch in the thin film of corrosion products on the surface of the tubes is likely to form the nucleus of a pit of corrosion which may widen, deepen, and cause tube failure.

4. Clean outside of tubes with compressed air.

5. Reassemble, using new gaskets.

AIR EJECTORS

In most ships, the first and second stages of the air ejectors and their condensers have been combined into one complete assembly. In many ships, the gland exhaust condenser has been incorporated within the shell of the after condenser. The shell is rectangular, and is divided by a longitudinal plate into the inter condenser and the after condenser sections. A baffle at the gland vapor inlet deflects the air and vapor downward over the lower bank of tubes in the after condenser section.

In order to provide for continuous operation, two sets of nozzles and diffusers are furnished for each stage of the air ejectors. Only one set is necessary for operation of the plant; the other set is maintained ready for use in case of damage or unsatisfactory operation of the set in use. The two sets can be used simultaneously when excessive air leakage into the condenser necessitates additional pumping capacity.

An inter stage valve is provided between the discharge of each first-stage ejector and the inter condenser so that the pressure built up by the first-stage jet, in operation, will not be lost back to the condenser through the idle first stage. For a similar reason, a cutout valve is located between each second-stage suction chamber and the inter condenser. By means of diaphragm plates in the inlet and outlet heads, the cooling water (condensate) is forced to make several passes through the unit before being discharged.

The atmospheric vent is usually connected to the suction of a small motor-driven fan (gland exhauster), which provides a positive discharge through piping to the atmosphere above decks. This is necessary to avoid filling the engineroom with steam should the air ejector cooling water supply fail, thereby allowing the steam to pass through the inter condenser and after condenser without being condensed.

OPERATION OF AIR EJECTORS

With each air ejector assembly installed, the manufacturer furnishes technical manuals to provide information on operation and maintenance. General information on starting, shifting, and securing air ejectors is given in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D, and *NAVSHIPS Technical Manual* Some additional items for air ejector operation are as follows:

1. Before starting a steam air ejector, the steam line should be drained of all moisture; moisture in the steam will cut the nozzles, and slugs of water will cause unstable operation.
2. Before cutting steam into the air ejectors, make sure that sufficient cooling water is flowing through the condenser and that the condenser has been properly vented.
3. The loop seal line must be kept airtight; an air leak may cause all water to drain out of the seal.
4. If it is necessary to operate both sets of air ejectors to maintain proper condenser vacuum, air leakage is indicated. It is more desirable to eliminate the air leakage than to operate two sets of air ejectors.

Unstable operation of an air ejector may be caused by any of the following: the steam pressure may be lower than the designed amount, the steam temperature and quality may be different than design condition, there may be scale on the nozzle surface, the position of the steam nozzle may not be right in relation to the diffuser, or the condenser drains may be stopped. up.

Difficulties due to low pressure are generally caused by improper functioning or improper adjustment of the steam reducing valve supplying motive steam to the air ejector assembly. It is essential that DRY steam at FULL operating pressure be supplied to the air ejector nozzles.

Erosion or fouling of air ejector nozzles is evidence that wet steam is being admitted to the unit. Faulty nozzles make it impossible to operate the ejector under high vacuum. In some instances, the nozzles may be clogged with grease or some other deposit which will decrease the jet efficiency.

MAINTENANCE OF AIR EJECTORS

In general, it is possible to clean air ejector nozzles by using reamers. The proper size reamer should be used for each size of nozzle, to avoid damage to the nozzle. If it is necessary to remove the nozzle for cleaning or replacement, the internal surfaces must not be damaged. Dents or deformations of the downstream end of the nozzle, and rough or scratchy surfaces in the throat or diffuser passages will result in improper operation of the unit. Foreign deposits present on the internal surface of the nozzle or diffuser should be removed by the use of nozzle reamers, soft copper wire, or a piece of wood.

Before disassembly or reassembly of nozzles or diffusers is undertaken, the manufacturer's technical manual should be consulted. If replacement of a nozzle or diffuser is required, gaskets of proper thickness must be used for reassembly. It is essential that the nozzle and the diffuser tube be concentric and in proper alignment and that the correct distance be maintained between the ends of the nozzle and the diffuser.

It is possible to clean or replace steam strainers, nozzles, or diffusers, of an air ejector assembly while the rest of the unit is in operation. It is necessary to isolate the unit which is to be opened from the rest of the assembly, by closing the steam supply valve and the inter stage valves of this unit, to avoid burns being suffered by personnel engaged in this work.

In installations where separate inter and after condensers are provided for each element, isolating valves are not required. In some installations where a common after condenser is provided for two second-stage elements, the internal construction of the unit is such that the steam discharged from the operating element cannot back up through the diffuser of the second-stage element, and isolating valves are omitted from the second-stage diffuser discharge.

Division Plate Leakage

Should internal leakage occur across the division plate between the inter condenser and the after condenser, the second-stage element becomes overloaded since the air-steam mixture discharged by the second-stage element leaks back to the inter condenser instead of being discharged to the atmosphere. A leak of this type rarely happens in modern air ejectors, but if it is suspected, the inter condenser or the after condenser should be hydrostatically tested and the condenser drains should be inspected to determine whether leakage is indicated. Repairs involve removal of tubes, disassembly of the unit, and replacement of internal gaskets.

Flooded Condenser

Improper drainage or leaking condenser tubes will cause flooding of the inter and after condensers, which will result in a loss of vacuum. If flooding should occur, the effective condensing surface is decreased, and a loss of vacuum occurs. Flooding may also cause condensate to be drawn into the second-stage element, which will result in erratic operation of the unit.

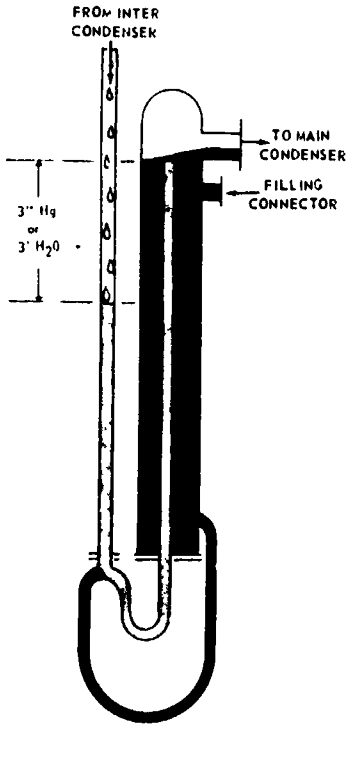
If flooding is suspected, drain lines should be cleared out and a hydrostatic test should be placed on the unit to check for leaks at tube joints and tube walls. Tubes rarely need replacing; most installations use condensate as a cooling medium.

If tube leakage does occur, the packed ends can be repacked by use of copper-asbestos packing rings supplied by the manufacturer. The removal of old packing rings and installation of new ones can be accomplished in the same manner as described in this chapter for packing of main condenser tubes except that copper-asbestos rings should be set up with several very light hammer blows on the calking tool. Copper does not flow into the threads of the packing box as readily as does the lead packing used in main condensers.

Emergency repair of a tube is accomplished by plugging both ends. Should retubing or other major repairs be necessary, all parts of the assembly should be hydrostatically tested to the test pressure specified by the manufacturer. It should be determined that all internal parts of the assembly are in proper working order before the new tubes are installed. A positive test should be made to establish the tightness of the gaskets between the inter and after condensers both before and after installing new tubes.

Maintaining the Loop Seal

Should an air leak be present in the U-shaped loop seal line (fig. 5-7) provided for draining the inter condenser, it will become impossible to maintain a seal between the inter condenser and



96.29

Figure 5-7.—Loop seal.

the main condenser. Water from the inter condenser passes down through the small 1-inch pipe, then through the short loop, and up through the internal pipe. The larger pipe surrounding the internal pipe is 3 inches in diameter and is connected to the main condenser. Water overflowing the internal pipe fills the external pipe and the larger loop.

If no vacuum existed in either condenser, and water from the inter condenser entered the internal pipe, it would maintain the same height in each leg.

When a vacuum is formed in both condensers, the difference between the vacuum maintained in the main condenser and that maintained in the inter condenser will be about 3 inches. The vaccum in the main condenser will be about 29 inches, that in the inter condenser about 26 inches. Expressing vacuum in terms of absolute pressure, a pressure of 1/2 psi will be acting down on the internal and external pipes, and a pressure of 2 psi will work down against the water level in the primary 1-inch pipe. This means that the pressure of 2 psi from the primary pipe will push water through the pipe and cause it to overflow from the external pipe into the main condenser.

When the water level in the primary leg is approximately 3 feet below that of the secondary leg, the additional weight of the water present in the secondary leg will provide the extra 1 1/2 psi necessary to counteract the 2 psi absolute pressure against the primary leg. Thus, a static condition will be obtained. If water is added, from the inter condenser, to the primary leg, the level on that side will rise, and the additional weight of the water will cause water to be pushed into the main condenser, from the secondary leg, thereby restoring the loop to its original static condition.

Adding water to one side of the loop and removing it from the other side is the means by which water is drained from the inter condenser to the main condenser. A solid body of water is maintained in the base of the loop and prevents air from passing through which would cause an equalization of vacuum.

The purpose of the filling connection is to allow condensate to be pumped from the condensate pump discharge line to the loop seal so that the loop may be filled before placing it in operation. A cutout valve is installed in the line from the loop seal to the main condenser.

If the vacuum gages on both the main and inter condensers show the same reading, this indicates that the seal has been broken. Opening the filling valve will correct this condition, if it is due to a sudden surge in vacuum, or a violent roll of the ship. If the condition is the result of an air leak, the leak will have to be corrected before the loop will remain properly sealed.

CHAPTER 6

PUMPS

This chapter contains information on the inspection and repair of reciprocating and centrifugal pumps and on the operation and repair of pressure regulating and speed limiting governors. As an MM1 or MMC you will be responsible for operation and maintenance of pumps and governors in the engineroom and other assigned spaces.

RECIPROCATING PUMPS

Reciprocating pumps were once widely used aboard Navy ships for a variety of services. At present, centrifugal and rotary pumps are far more common. Use of reciprocating pumps on combatant ships are now generally restricted to emergency feed pumps, fire and bilge pumps, and fuel oil tank stripping and bilge pumps. On auxiliary ships, reciprocating pumps are still used for a number of services, including auxiliary feed, standby fuel oil service, fuel oil transfer, auxiliary circulating and condensate, fire and bilge, ballast, and lube oil transfer.

MAINTENANCE OF RECIPROCATING PUMPS

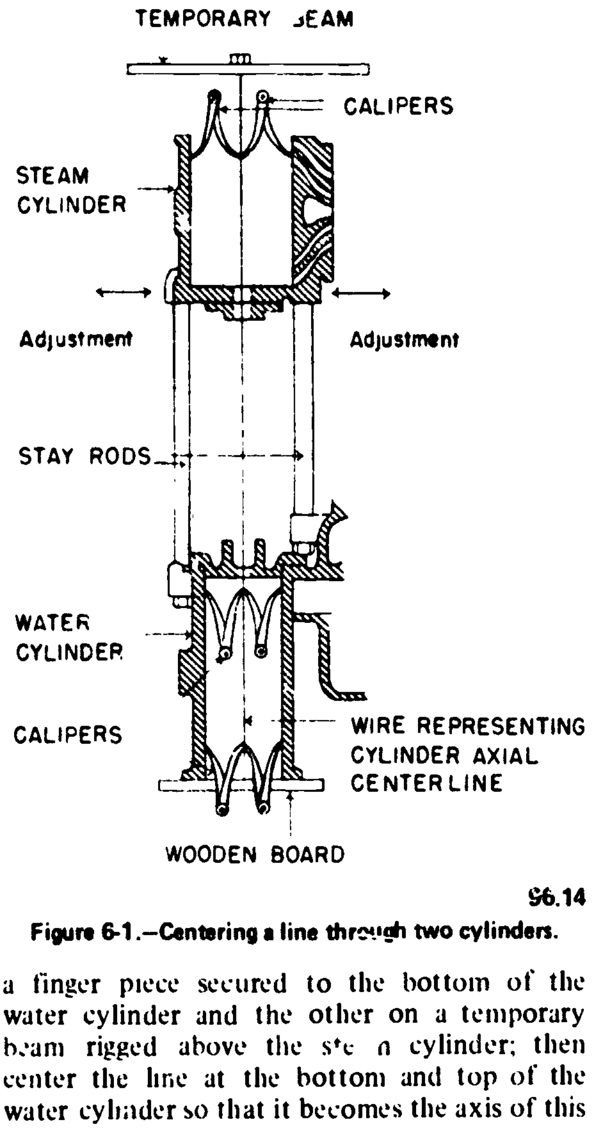
When repairs are undertaken, the repairs must be accomplished in accordance with the 3-M System. The system ensures that every part of the pump which required attention or contributed to poor performance is put into proper condition. When a partial overhaul is undertaken, check "NOT DONE" for items that are not repaired. This will show that every part was inspected and either worked on or not worked on. Upon completion of a pump overhaul, the repair data list can be kept as a permanent record of all measurements taken and all work done.

When a pump is disassembled for repair or inspection, all applicable blueprints, the manufacturer's technical manuals, and available dimensional data should be on hand. Micrometer measurements should be taken of the steam and water cylinders and the steam valve chest; these measurements are made on the fore and aft and athwartship diameters at the top, middle, and bottom. The results should be recorded with a sketch showing measurements taken.

Improper alignment is one of the most frequent sources of trouble with pumps. Pumps with mountings secured to a bulkhead are more subject to misalignment than those with independent bases. A pump may have been properly aligned in the shop and then pulled out of line when bolted to the bulkhead mounting; or after the pump mounting was secured, the ship may have changed shape sufficiently to warp the bulkhead and cause misalignment.

Operation of an improperly aligned pump usually scores the rods and cylinders, and breaks the followers. The alignment of pumps should be tested occasionally by removing the piston and plunger and running a line through the steam and water cylinders. This should be performed as a routine test within the first year after a ship is commissioned; and also for a pump that is scoring rods or cylinders, or breaking followers.

Before a line is run through the cylinder or any adjustments are made, the foundation must be lined up and the centerline must be determined. The centerline must divide each cylinder equally (fig. 6-1). Fasten one end of the line on



96.14

Figure 6-1.—Centering a line through two cylinders.

a finger piece secured to the bottom of the water cylinder and the other on a temporary beam rigged above the steam cylinder; then center the line at the bottom and top of the water cylinder so that it becomes the axis of this cylinder as shown in figure 6-1. The steam cylinder can now be moved about and centered on the line without disturbing the centering of the line on the water cylinder.

To make a rough check of alignment of a pump, pull the steam and liquid end rod packing and check the clearances between the piston rods and the cylinder throat bushings. Make this check with the pistons in each of three positions top, center, and bottom of the stroke. If clearance is not uniform, but the throat bushings are not worn out of round, realign the pump as soon as possible.

In some cases, when steam cylinder foundation pad bolts are slacked off, the cylinder pads pull away from the foundation as much as 1/2 inch, indicating settling of foundations and bulkheads. Correct this by fitting shims between the foundation and the pump.

A frequent cause of misalignment is the piping. The piping should line up naturally with the pump connections and should not be forced into position. Provision must be made in steam and exhaust lines to allow for expansion. All piping should be supported independently of the pump. Improperly installed piping puts a strain on the pump and forces it out of alignment. Special care should be taken to avoid vapor pockets when installing suction piping.

OPERATION OF RECIPROCATING PUMPS

Operating difficulties with reciprocating pumps will be encountered from time to time. Some of the most common causes of trouble and their remedies are mentioned in the following sections.

Failure To Start

There may be times, after you have lined up the pump and cracked open the throttle valve, that the pump will not start. You may repeat the starting procedure, and determine that everything seems to be all right, but still the pump will not start. At this point, proceed as follows: Secure the pump. Check the suction, discharge, and auxiliary exhaust lines for a closed valve, or for a valve disk that has come off its stem. If no valves are closed, the water piston or the steam piston may be frozen, especially if the pump has been idle for some time. This may be determined by jacking the pump with a bar.

CAUTION: Never attempt to jack a reciprocating pump unless you are certain that the throttle valve and the exhaust valve are closed tightly and the steam cylinder and steam chest drains are wide open.

If there is no excessive friction, disconnect the auxiliary valve stem from the operating gear without disturbing the adjustment of the tappet collars. Open the exhaust, suction, and discharge valves and then crack the throttle. Work the auxiliary piston valve by hand (the auxiliary valve should work freely). Should the pump still not start, secure steam and water end valves. Remove the steam valve chest to determine whether the main piston valve has overridden or stuck.

If the pump still cannot be started, a complete overhaul of the working parts of the steam end will be necessary.

Failure To Take Suction

When a reciprocating pump fails to take suction, the operation will be jerky. To correct this, proceed as follows: See that all stop and check valves in the suction line are open. Ensure that the suction line is free of all obstructions. If a reciprocating feed pump should become vapor bound, shift suction to a standby feed tank and open the vent valves in the valve chest cover and the discharge line to help cool the pump. Shift to the standby feed pump, if available, until the vapor-bound pump cools off.

Pumps having a suction lift, such as bilge pumps, may require priming before they will take suction. Salt water pumps can usually be primed from the sea by opening the sea suction for a short interval.

If failure to take suction is due to defective valves in the water end, the defects will have to be corrected before the pump will operate satisfactorily.

Loss of Discharge Pressure

There are several reasons for a reciprocating pump to lose discharge pressure, some of the major reasons are:

1. Low steam pressure. Loss of steam pressure will cause the pump to slow down and will result in a loss of pump capacity and discharge pressure.

2. High back pressure. If the auxiliary exhaust pressure is allowed to become abnormally high, it will cause the pump to slow down and the discharge pressure will drop.

3. Worn piston rings. Leakage of steam by worn piston rings will cause the pump to operate erratically or even to stop. When worn rings are suspected, the steam end should be disassembled and the ring and piston measurements should be taken. If measurements are below the designed allowances, the rings will have to be renewed.

4. Defective valves. If a pump is operating normally and suddenly loses discharge pressure, a defective valve should be one of the first things to suspect. A large loss in efficiency will result from defective valves. If a pump races without increasing the discharge pressure, defective valves of air leaking into the suction line will probably be the cause.

5. Worn plunger packing. Another reason for a pump losing discharge pressure is worn packing on the water end plunger. The packing will wear, over a period of time, and the maximum discharge pressure from the pump will decrease accordingly; the only remedy is to renew the packing. Worn plunger packing should be renewed in accordance with the procedure given in chapter 6 of *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D, or in the instructions in the manufacturer's technical manual.

When you are trying to locate and correct troubles in a reciprocating pump, previous experience with a particular pump is always helpful. The first step should be to check all accessible parts. If the trouble cannot be located without disassembling the pump, the water end should be checked and determined to be satisfactory, before you remove any parts from the steam end. Most pump troubles are due to foul water cylinders, worn valves, or conditions in the pipe connections external to the pump.

CENTRIFUGAL PUMPS

Centrifugal pumps are widely used aboard ship for pumping water and other nonviscous liquids. Centrifugal pumps have several advantages over reciprocating pumps: They are simpler, more compact, lighter, and easily adapted to a high speed prime mover.

Centrifugal pumps also have disadvantages: They have poor suction lift characteristics in order to operate on a suction lift; they are also sensitive to variations in head and speed.

Centrifugal pumps are usually designed for specific operating conditions and will not give satisfactory results when their rated operating conditions are altered. Before installing any centrifugal pump, it is important to understand the principle of operation and design limitations of the specific pump.

OPERATION OF CENTRIFUGAL PUMPS

The details of operation for a centrifugal pump may vary from pump to pump. Pumps may look alike but this does not necessarily mean that they are operated in the same manner. Detailed instructions for operating a specific pump should be posted near the pump. Before operating the pump, the instructions should be carefully read. Read the label on all valves that apply to the pump. Check the markings on all piping that leads to or away from the pump and the pump's driving unit.

Many casualties that occur to pumps affect the speed of the ship. Many pump casualities, caused by improper operation, could be prevented by attentive watchstanding. Strict adherence to the engineering operating procedures and manufacturer's instructions for starting, operating, and securing pumps will help prevent casualties.

Starting A Centrifugal Pump

The instructions contained in this chapter for the operation of pumps are general. All pumps cannot be covered because of the large number of makes and types of pumps installed aboard naval ships. Manufacturer's technical manuals are furnished with all but the simplest of pumps. These manuals contain detailed instructions concerning the specific pump and should be studied carefully before you attempt to operate the pump.

Prior to starting a centrifugal pump for the first time or after an overhaul, there are several items that should be checked. The coupling alignment must be carefully checked. Flexible couplings will take care of only very slight misalignment, usually about 0.002 to 0.004 [illegible]. The exact figure can be found in the manufacturer's instructions. Excessive misalignment will cause the coupling to fail and may result in failure of the pump shaft or bearings.

If the pump is motor driven, the rotation of the unit should be checked. Most pumps have an arrow, on the pump casing, which indicates the proper direction of rotation.

Check all piping that pertains to the pump. During overhaul, most valves in the piping will have been closed. The lube oil system, the suction, discharge, vent, recirculating, and bypass valves must be lined up properly. An adequate supply of water must be available for the lube oil cooler; and inlet, outlet, and root valves should be checked.

When starting a steam-driven centrifugal pump, some of the important items to check or perform are as follows:

1. Check the level of oil in the sump tank or bearing housing. Fill oil cups or reservoirs, if fitted. If the pump is lubricated by a detached pump, open and adjust all valves in the discharge and suction lines.
2. Rotate the handle of the lube oil filter. Lubricate the linkage on the speed limiting governor.
3. Open the suction valve, the vent, and recirculating valves; open valves in gland water seal lines (if fitted). (The discharge valve should be closed when starting centrifugal pumps.)
4. Open steam and exhaust root valves.
5. Check the suction pressure (if applicable).
6. Open all steam drains.
7. Open the turbine exhaust valve.
8. Open the bypass around the governor (if fitted).
9. Crack the turbine throttle valve.
10. Increase the steam chest pressure until the pump is turning fast enough to ensure adequate lube oil pressure.
11. Check packing glands for proper leak-off.
12. When the pump vent blows a solid stream of water, close the vent.
13. Close pump governor bypass and test the constant pressure governor.
14. When lube oil temperature reaches 90°F, open valve for cooling water to the lube oil cooler.
15. When ordered to put the pump (not fitted with a pressure governor) on the line, increase

the pump discharge to the required amount by opening the throttle valve to necessary speed. If the pump is fitted with a constant pressure governor, set the governor to give the required discharge pressure.

16. When the pump is delivering the required discharge pressure, open the pump discharge valve

Note: These items are not necessarily listed in any proper order and all items do not apply to all steam-driven pumps. Operate the pump in accordance with the ship's engineering operating procedure.

Operating A Centrifugal Pump

When pump has been started, it should not be left unattended. An experienced man should be on hand to check for abnormal operation Frequent checks should be made on the temperature of the lube oil leaving the cooler and leaving each bearing. The suction and discharge pressures may become too high or too low. Packing glands may overheat and burn out.

The principal troubles that may occur with centrifugal pumps are:

1. Low discharge pressure. There are several reasons why a pump will not discharge at maximum capacity or pressure. The pump may be improperly primed, thus the proper quantity of liquid does not reach the pump casing. The speed of the pump may be too slow. On a turbine-driven pump, the speed limiting governor may be set too low, or the constant pressure governor may need adjusting. The pump may have mechanical defects such as worn wearing rings, worn bearings, a bent shaft, or a damaged impeller.

2. Loss of suction. If a pump has been operating satisfactorily and loses suction, air may be entering the suction line or packing glands. The suction strainer may have become clogged, or dirt or other foreign matter may have entered the impeller opening. In a main feed pump, the main feed booster pump may not be operating at its normal discharge pressure.

3. Excessive vibration. In a pump, excessive vibration may be due to one of the following causes: misalignment of the unit, a sprung foundation worn impeller rings, worn bearings, a bent shaft, an improperly balanced impeller, or a broken impeller.

When putting a main feed pump on the line, make sure that the main feed booster pump is maintaining the required pressure. Boiler feed water is discharged under pressure from the main feed booster pump to the suction side of the main feed pump, which in turn discharges the feed water through the feed line to the boiler at a high pressure.

There are two sets of wearing rings in each stage. These wearing rings are designed with a minimum of clearance, as are the rings in a main feed booster pump, but the rotation of a main feed pump can be five times as great as that of a main feed booster pump, so the possibility of seizure of the main feed pump wearing rings is much greater.

Water entering the suction of the main feed pump has its pressure reduced while passing through the entrance ports; since this water is at a temperature of about 240° F, this reduction in pressure might easily cause the water to flash into steam. If this occurs, the pump will become vapor bound, which prevents the flow of water through the pump and therefore prevents the removal of heat from the pump casing. A vapor-bound feed pump will require about 15 seconds to overheat, causing the wearing rings to seize.

The main feed booster pump discharge should be maintained at as near the designed value as possible. For an installation designed to operate at 50 psi of booster pressure, the main feed pump should not be turned over when there is less than 40 psi of booster pressure.

When main feed pumps are running, ensure that the oil temperature and pressure at the bearings are in accordance with the manufacturer's operating instructions. If a detached lube oil pump is provided, it will automatically cut in if the lube oil pressure falls below a predetermined amount. If low lube oil pressure develops after the detached lube oil pump starts, shift to the standby unit, secure the faulty unit, and determine and correct the cause of low lube oil pressure. On installations where no detached lube oil pump is provided and low lube oil pressure occurs, shift immediately to the standby unit and do not operate the faulty pump until the proper lube oil pressure has been restored.

There is a common tendency to tighten packing glands too tightly. This causes the packing to burn and leads to scoring of the shaft sleeves. The packing glands should be adjusted so that a small amount of water is leaking out of the stuffing boxes. This water lubricates and cools the packing and packing gland. The packing gland should always be parallel to the face of the stuffing box and not cocked at an angle. If a stuffing box leaks excessively, and it becomes necessary to tighten the gland, take up evenly on the gland bolts a slight turn. Wait a reasonable time, and if the leakage is still excessive, tighten the gland bolts another slight turn. This procedure should be continued until there is only a trickle of water from the stuffing box.

When a main feed pump is running do not change from hot to cold water or vice versa, unless there is an extreme emergency. Make periodic checks for vibration of the pump and driving unit. If vibration becomes excessive, stop the pump and investigate.

When a main circulating pump is used to pump the engine room bilges, the pump should be started the same as for main condenser circulating service; then, the main injection valve should be gradually closed and the bilge suction valve opened When the pump is operating on a high suction lift, as when pumping bilges, the speed should be reduced to about two-thirds of rated speed and even when so operated, the pump will be noisy. This cannot be avoided, but can be minimized by slowing the pump.

Securing a Centrifugal Pump

To secure a steam driven centrifugal pump, proceed as follows:

1. Close the pump discharge valve.
2. Close the throttle valve.
3. Close the exhaust valve
4. Close the suction valve.
5. Close the vent, recirculating, and gland sealing valves. (On some units, recirculating and vent valves are locked open.)
6. Open the turbine casing drain
7. Close the steam and exhaust root valves.
8. Close the turbine casing drain after the turbine is completely drained.

MAINTENANCE OF CENTRIFUGAL PUMPS

This chapter contains some of the information you must have in order to give proper care and maintenance to centrifugal pumps. Before attempting to repair any pump, the manufacturer's technical manual and the maintenance records for the pump should be studied carefully.

Bearing Maintenance

Pump bearings must receive approximately the same tests, inspections, and maintenance as bearings installed in other units of naval machinery. Pump bearings must be supplied with an adequate amount of oil at the right temperature and of the viscosity designated for that particular pump. The manufacturer's technical manual contains information on lubrication of each pump.

THRUST BEARINGS should be examined quarterly. The condition of the bearing and the position of the rotor should be checked. When checking the rotor position, allowance should be made for expansion of the shaft from cold to hot condition. There are many types of thrust bearings installed in pumps; and the manufacturer's technical manual should be checked before attempting disassembly of any thrust bearing.

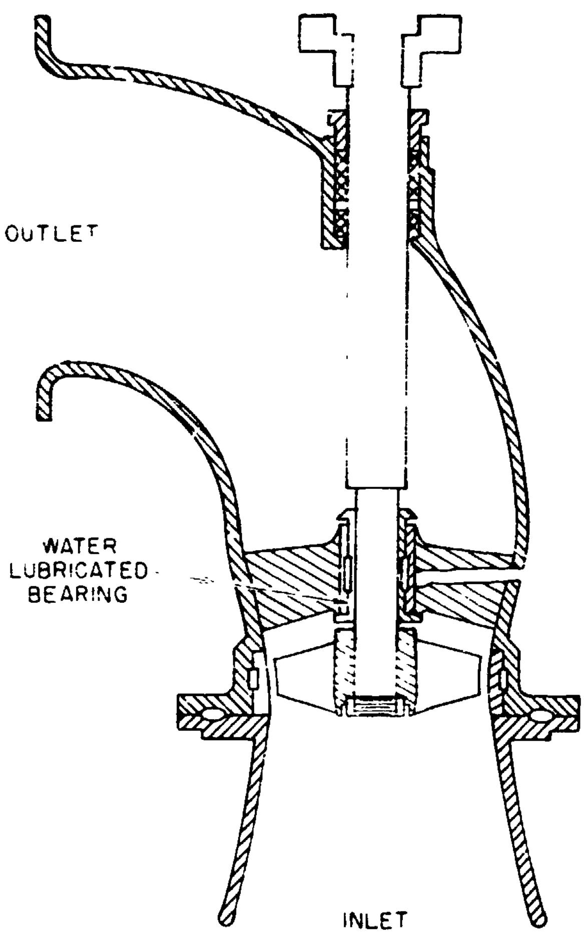
JOURNAL BEARINGS should be systematically inspected. The condition of the journal and the bearing surface should be checked and any deficiencies corrected. Lead readings should be taken and bearing clearances should be maintained as shown in the manufacturer's plans. If the manufacturer's technical manual is not available, the instructions in chapter 9400 of *NAVSHIPS Technical Manual* should be followed.

WATER-LUBRICATED BEARINGS are installed in main condensate pumps and main circulating pumps. In main condensate pumps, the bearing is located in the casing, between the first-stage and second-stage suction compartments, where it also serves as an interstage seal.

Vertical movement of the bearing is prevented by shoulders in the casing, and a stop pin prevents angular movement. During normal operation of the pump, the bearing is lubricated by a constant flow of water through the bearing which is maintained as a result of the pressure differential between the two suction compartments.

In main circulating pumps (fig. 6-2), the water-lubricated bearing is located immediately above the propeller and is designed for a radial load only. The bearing is held in place by shoulders in the casing and is lubricated by the flow of water through the pump.

A number of materials have been used for water-lubricated bearings, such as leaded bronze, graphited bronze, lignum vitae, laminated phenolic material grade FBM (fabric base



96.15

Figure 6-2.—Main condenser circulating pump, showing internal water-lubricated bearing.

bakelite or micarta), and barium; most water-lubricated bearings are now made of rubber or phenolic composition.

The condition of water-lubricated bearings should be checked frequently to guard against excessive wear which would cause shaft misalignment and possible bearing wear or shaft breakage.

BALL and ROLLER BEARINGS are used in many shipboard pumps, especially in small pumps, and in main condensate, main feed booster, and lube oil service pumps. These bearings must be handled as carefully as any other piece of precision equipment. The following precautions will aid in proper bearing maintenance:

1. Do not remove the bearing from its container until you are ready to install it.
2. Be certain that the journal, housing, or any other mating part is of the correct dimensions.
3. Avoid damage during handling; do not drop the bearing; keep dirt and moisture away from the bearing, shaft, and housing.
4. Use proper tools for removing the old bearing and installing the new bearing.
5. Use the correct lubricant and the proper amount. After assembly, the journal should be rotated by hand to ensure that there is no undue friction.

In rolling contact bearings, the journal is supported by the races and rolling elements, rather than the oil film; however, lubrication still plays an important part in the operation because it dissipates heat and prevents corrosion. The oil film also helps prevent foreign matter from entering the bearing. Enough grease or oil should be supplied to provide a protective film over the bearing parts; using an excessive amount of lubricant will cause it to churn and the bearing will overheat.

When a roller or ball bearing fails in service, it must be renewed as it cannot be repaired. The replacement bearing must be carefully installed if it is to give satisfactory service.

Lubricating Systems

Lack of lubrication or improper lubrication is a major cause of pump failure. Before a pump is started, the level of oil in the sump should be checked not only for the amount of oil, but also for the quality of oil it contains. If water is found in the oil sump, check for leakage from turbine glands, a leaky oil cooler, or any other possible source of water contamination. The oil filters or strainers must be checked frequently; in those with edge filtration (such as in the Cuno type filter), the sediment, which will collect in the bottom of the filter, must be cleaned out frequently. Housings of grease-lubricated bearings should be checked occasionally to ensure that they are free of water, dirt, and other foreign matter. If water is found in the bearing housing, it should be traced to its source. The frequency with which grease is added to a bearing must be determined by the type of service and the effectiveness of the grease seals.

When starting a pump, check the oil pressure and the flow of oil to all bearings. Make sure that the lube oil pump is discharging at the designed pressure. Ensure that cooling water is flowing through the oil cooler and that all air is vented from the cooler. It may be necessary to vent the lube oil system. To do this, open the vent on the highest point in the lube oil system and close the vent when oil appears.

When water or other foreign matter is found in a lube oil system, the unit should not be operated until the system has been drained, cleaned, and filled with the proper quantity and quality of oil.

Replacing Pump Rotors

Pumps, like all machinery, in time, will need overhauling. Much of the work on pumps involves removing the rotor from the casing. To renew wearing rings, bearings, packing, sleeves, or impellers, the casing must be removed and the rotor lifted out.

In order to disassemble a MAIN FEED PUMP the following procedure is recommended:

1. Close and lock shut all suction, discharge, vent, and recirculating valves. Drain water from the casing.
2. Remove all suction, discharge, vent, and recirculating lines that will interfere with lifting the casing and rotor.
3. Remove the bearing caps and the bearings (journal and thrust).
4. Disconnect the coupling between the turbine and pump.
5. Remove the packing glands and the packing.
6. Remove the pump casing horizontal joint bolts.
7. Break the horizontal casing joint by tightening the jack screws.
8. Attach the lifting gear to the upper half of the casing (eyebolts are provided for this purpose).
9. Lift the upper half of the casing until it is clear of the rotor. Change the lifting gear and swing the upper casing half clear of the pump.
10. Attach cables around the shaft at both ends, making certain that you do not lift on a journal surface, and lift the rotor out of the lower half of the casing.
11. The rotor can then be moved to a location where it can be disassembled. In order for you to have access to all rotor parts, the rotor should be placed on a workbench, or if available, two wooden sawhorses.

Remove all rotor parts in the sequence and in the manner recommended by the manufacturer.

It may be necessary to heat the impellers in order to remove them. If so, warm the impeller evenly all around, while keeping the shaft as cool as possible.

When the rotor parts are disassembled, the shaft should be checked carefully. The journal surfaces should be checked for burrs or nicks. If a lathe is available, the shaft can be swung in the lathe, and with a dial indicator, you can determine whether the shaft is bent or the journals are out of round. The journal surfaces can be measured with an outside micrometer to determine whether there is wear. If the journals are worn or out of round, they can be built up and machined to the designed diameter, at a repair activity. If the wearing rings are to be renewed, they will have to be fitted either in the ship's machine shop, or at a repair activity.

Before starting to REASSEMBLE the rotor make sure that all parts are clean and free of burrs (especially the faces of the impeller and the sleeves).

The oil clearances of the journal and thrust bearings, the running clearance of the wearing rings, the clearance between the impeller and diaphragm bushing, and clearance between the shaft sleeve and stuffing box bushing should be within the limits indicated in the manufacturer's technical manual.

Before lowering the rotor, roll in the lower half of the journal bearings. Clean all dirt and foreign matter from the lower half of the casing. A new parting flange gasket should be used to avoid leaks, as internal leaks will lower the efficiency and maximum capacity of the pump.

Attach the lifting gear and lower the rotor into the casing. Make sure that all stationary rotor parts: diaphragms, casing rings, and stuffing box bushings will enter their respective fits in the casing without binding. If force has to be applied to the rotor parts, in order for them to enter the casing, remove the rotor and check all parts for dirt and burrs.

When the rotor is in place, lower the upper half of the casing. Ensure that the casing fits over the rotor easily. If it does not, remove the upper casing half and examine it for dirt and burrs. When the upper and lower casing halves contact each other properly, insert the casing dowels. Next, tighten the parting flange nuts, tighten them evenly by going over them several times. Assemble the thrust bearing, then place the upper half of the bearings in position and bolt the two halves of each together. Adjust the flingers: they should be close to the face of the bearings but MUST not rub. Tighten the flinger setscrews and close up the bearings by placing the caps over them and tightening the bolts. Take a reading on the thrust bearing clearance.

The pump shaft and turbine shaft MUST be in correct alignment. For information on pump alignment, refer to the manufacturer's technical manual, *NAVSHIPS Technical Manual*, or chapter 6 of *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

All water lines MUST be in place and tightened before you attempt to align the unit: otherwise tightening the lines may cause misalignment of the unit. Pack the stuffing boxes with the proper packing, then the unit is ready to be tested.

Rotate the pump several times, by hand, before steam is cut into the driving unit. Ensure that there is no undue binding or friction.

The procedure for replacing a MAIN CONDENSATE PUMP ROTOR or a MAIN FEED BOOSTER PUMP ROTOR is similar. These pumps are usually vertically mounted and the rotor can be disassembled without disturbing the driving unit. The procedure is as follows:

1. Obtain the applicable manufacturer's technical manual and blueprints. Study the construction details and procedures for assembly and disassembly. Note the manufacturer's data on wearing ring clearances, bearing clearances, and other necessary dimensions. Check the maintenance records; alterations may have been made.

2. Remove the new rotor from its storage place. Clean and inspect the new rotor; take all necessary measurements.

3. Assemble all necessary lifting gear and tools, including special tools.

4. Remove the nuts at the parting flange and remove the casing half. Take off the bearing cap, unbolt the bearing housing, disconnect the coupling, and lift out the old rotor.

5. Inspect the interior of the casing, clean all flanges and make new gaskets. (New gaskets should be used on all flanges as any leakage through a main condensate pump flange will result in a loss of vacuum in the main condenser.)

6. After the cleaning and inspecting are done, lower the new rotor into place.

7. Place the casing in position and tighten the parting flange nuts. If the casing binds or does not fit properly, remove the casing and correct the trouble.

8. When the casing has been secured in place, the rotor should be rotated by hand to ensure that there is no binding or undue friction.

9. Reassemble the bearing housing and connect the coupling. If the pump still turns freely, the unit is ready to be tested by steam (or motor). If all conditions are satisfactory, bring the pump up to operating speed and pressure. When the pump is used for the first time, it should be kept under close observation for several hours and should not be considered ready for unlimited operation until it has carried the required load with the ship under way.

Prepare a work request for the necessary repairs to the defective rotor. All necessary details, including balancing, should be written up and the rotor taken to the appropriate repair activity. All pump and driving unit rotating parts are balanced dynamically for all speeds from at rest to 125 percent of rated speed. The parts are usually dynamically balanced on balancing machines, generally available on tenders and repair ships and at all naval shipyards.

On ships with adequate shop facilities, pump rotors may be overhauled on board. The rotor should be taken to the machine shop and dismantled. The parts should be taken off the shaft in the sequence recommended by the manufacturer. When the parts have been removed from the shaft, the shaft should be checked in the same manner as previously described in this chapter for shafts of main feed pump rotors.

If the shaft is not bent or out of round, the parts can be reinstalled on the shaft, using new parts as needed. Ball bearings can be shrunk or pressed on the shaft. The best practice is to heat the bearing, in an oil bath, to about 200° F (but not exceeding this temperature), then slip it over the journal and position it by means of the locknut. The locknut can be tightened as the bearing cools.

Wearing rings should be given the clearance recommended by the manufacturer. When the rotor is reassembled, it should be properly stowed, so as to be ready for use when needed.

REPLACING ROTARY PUMP ROTORS

Generally, it is more difficult to replace main lube oil service pump rotors than rotors in other types of pumps. The driving unit must be removed before the liquid end can be disassembled. With the drive unit removed, the pump rotor and rotor housing can be disassembled without removing the mountings or the main lube oil connections

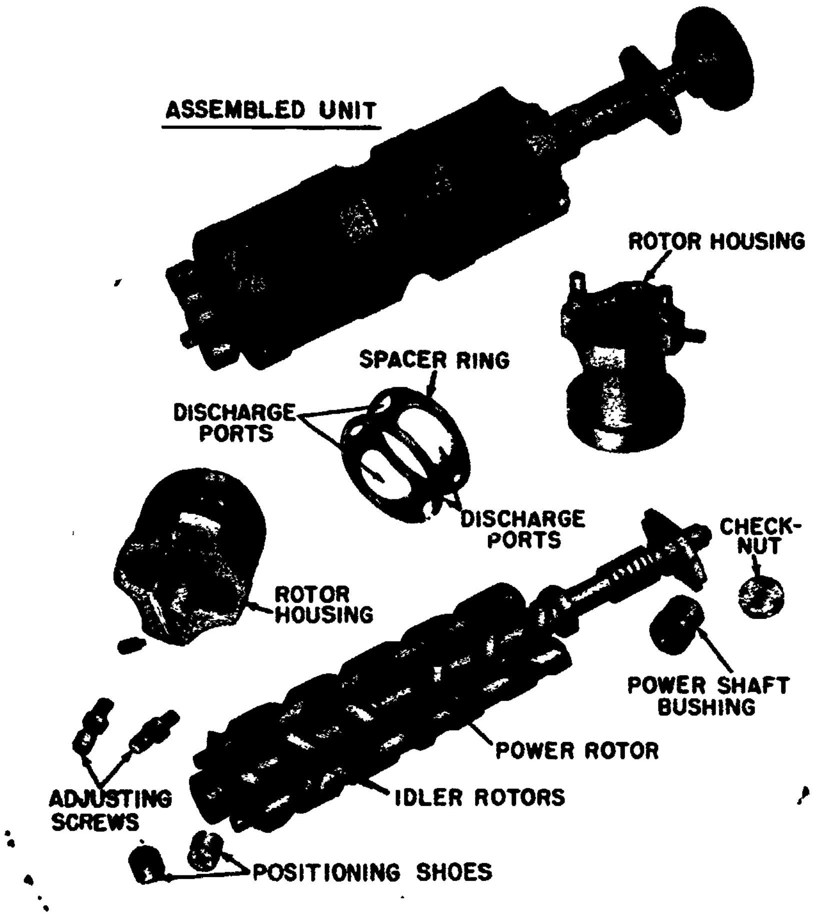
Under normal operating conditions, the rotors are completely covered with oil, which cuts rotor wear to a minimum. Therefore, the rotors may give years of satisfactory service without repairs. In some instances, rotor failure has been [illegible] to normal wear, air trapped in the casing, or entrance of dirt, wood, or metal objects into the casing. To replace a defective rotor, proceed as follows:

On a turbine-driven unit, remove the drive unit by breaking the steam and exhaust lines, disconnecting the coupling, removing the bolts which secure the spacing frame to the pump casing, attaching the lifting gear, and lifting the drive unit off intact.

To disassemble the liquid end (fig. 6-3), first remove the lower coupling half, the packing gland, and the upper casing head. The rotors will then be exposed and can be withdrawn. As the rotors are lifted out of their housings, the idlers must be supported; the pump is constructed in such a manner that only the housings hold the rotors in mesh. With the rotors removed, the housings are accessible. The housings fit snugly in the bore of the casing and are separated by a spacer ring. They are positioned axially by jam screws, which bear on the casing heads; and circumferentially by guide pins, which are fitted individually to ensure alignment of the housing bores. The guide pins are secured by pipe plugs. Before the rotor housings can be removed, it is necessary to take out the housing guide pins, the outer ends of which are drilled and tapped for the application of a pulling tool. Because these guide pins are fitted parts, each pin must be marked as it is withdrawn, so that it can be replaced properly.

Before the reassembling operations are started, all parts of the pump should be carefully inspected and cleaned. Also, it should be definitely ascertained that the settings of the lower housing jam screws are correct (check the manufacturer's technical manual or blueprint).

When reassembling the pump, lower the bottom housing, the spacer, and the upper housing into place separately. Ensure that each part seats firmly and that the guide pin slot in each housing registers with the pin hole in the casing. The special tool used for pulling the housings can also be used in assembling them. Next, install the housing guide pins and their securing plugs. If new housings are installed, the bores must be carefully aligned and new guide pins fitted to maintain alignment. The jam screws may then be set up in the upper housing.



38.107

Figure 6-3.—Rotor assembly for a lube oil service pump.

Insert the rotors and turn them by hand to see that they are free and do not bind. Binding of the rotors is an almost certain indication that the housings bores are not in line, or that the guide pins or the housings, or both, have not been properly installed. Install the upper casing head, making sure that the thrust plate and the seal bushing are in place and that the latter is secured by the stop pin provided for that purpose.

When a pump is assembled at the factory, the locating caps on the idlers are set up to establish the proper running positions of the idlers with reference to the power rotor, and are then secured by riveting. So long as a set of rotors remains intact, readjustment of the locating cap settings will rarely be found necessary. Even over long periods of service, wear of the hardened contact surfaces will be negligible.

Whenever new rotors are installed, the proper locating cap settings must be established. The proper cap settings are such that the lower end surfaces of all three rotors will lie in a common plane when the rotors are properly meshed and the idlers are located centrally with respect to end play in the power rotor.

The cap settings must be established before the rotors are installed, but the rotors should be inserted in one of the housings for the adjustments, to ensure proper meshing. A tapped hole is provided in the base of each cap, so that the pulling tool, or some other suitably threaded implement, can be used to jack the cap into position. After the settings have been established, the caps should be riveted into place; this entails drilling the shaft ends for the rivets. Rivet holes are provided in the caps of all idlers supplied by the factory.

SHAFT-DRIVEN LUBE OIL PUMPS are of the same size and design as the steam-driven pumps, but differ in their mountings and drive details.

Some pumps are hooked up to the main shaft through a sprocket and chain drive so that they operate continuously while the shaft is turning over. These pumps are designed with vertical shaft and horizontal shaft units.

On ships built since World War II, the attached lube oil pump is driven from the main reduction gear by an assembly of bevel and spur gears. The driving connection is made by a pinion, mounted on a hub, that is attached to the lower, low pressure, low speed pinion quill shaft coupling.

Before a chain-driven pump can be disassembled, the drive must be completely dismantled as follows:

1. Disconnect the oil lines leading to and from the chain housing.
2. Remove the chain cover.
3. Break and remove the chain. The manufacturer supplies a special tool and detailed instructions for breaking the chain.
4. Remove the lower section of the chain casing from its supporting frame.
5. For a vertical unit, remove the frame which supports the chain casing and houses the drive gears. The drive shaft mounting need not be disturbed for this operation.

With the driving mechanism out of the way, the horizontal pump can be dismantled in place, provided there is sufficient clearance for the withdrawal of the rotors. The vertical unit must be detached from its base and transferred to a location where both ends of the casing are accessible so that the rotors can be withdrawn.

If space permits, the rotors can be withdrawn from either end of the casing, but it is easier to withdraw them from the outer end (the end away from the drive unit), because this method does not require the removal of the inner casing head. (Removal of the outer casing head is a necessary step in the disassembling operation.)

Removal of the rotors from the outer end of the casing entails removing the sprocket, removing the outer casing head, freeing the rotors, and withdrawing them.

PUMP CONTROL DEVICES

Turbine-driven pumps are fitted with devices to control or limit the speed of the unit, or to regulate the discharge pressure of the unit.

SPEED LIMITING GOVERNORS

Speed limiting governors are set to give a rated speed at rated load conditions. With the governor properly set, the turbine speed should not exceed the rated speed by more than five percent, for any condition of load. If the governor will not function within the prescribed limit, it must be overhauled, and the cause of faulty operation located and corrected. Speed limiting governors should be inspected and tested in accordance with the 3-M System, and more often if ordered by NAVSEA, the type commander, or any other proper authority.

Chapter 6 of *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D, contains information on the principles of operation of a centrifugal weight type of speed limiting governor; briefly review this chapter if necessary. To set a governor of this type, remove the governor lever, and the governor cover. The governor spring will then be accessible. If it is desired to increase the maximum speed of the unit, the tension of the governor spring must be increased by tightening the adjusting nut. With increased spring tension, more centrifugal force will be required to move the weights outward–which in turn moves the sleeve outward against one end of the governor lever (moving the other end of the governor lever inward), closing down on the poppet valve, and decreasing the amount of steam flow to the turbine.

Decreasing the tension on the governor spring will allow the governor weights to move outward with less centrifugal force, thus decreasing the maximum speed of the unit.

Very little wear is experienced in a speed limiting governor, however, preventive maintenance is required. The governor must be kept clean. Dirt or other foreign matter can foul the spring, and thus require more force to move the weights, which will allow the pump to overspeed. Rust on the governor level fulcrum pin will cause the lever to bind and not function properly. All pins in the linkage and the valve stem must be kept free of paint, rust, and dirt so that the linkage can move freely. Occasionally, a test should be made to determine whether the poppet valve is leaking. The test may be made by pushing the valve onto its seat by hand. If the valve is leaking the turbine will continue to rotate.

CONSTANT PRESSURE PUMP GOVERNORS

Turbine-driven main feed pumps and fire pumps are fitted with constant pressure governors which control the discharge pressure of the unit by automatically controlling the amount of steam admitted to the turbine. (The principles of operation of a constant pressure governor are explained in chapter 6 of *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.)

The instructions for operation, care and repair of constant pressure governors contained in this chapter are general for all types of governors. For specific instructions, consult the applicable manufacturer's technical manual

One of the most common causes of trouble with a constant pressure governor is sluggishness due to dirt or foreign matter interfering with free movement of the working parts. To correct sluggishness, the governor must be taken apart and cleaned as follows.

1. Unscrew the connector union, remove the bottom nuts from the bolts holding the superstructure to the top cap, and then lift off the superstructure above the lower diaphragm. (When the superstructure is reassembled, care must be taken that the diaphragm stem, diaphragm stem cap, and diaphragm disk are put back in proper position. Make sure that the connecting rods are free and do not bind in their guides.)

2. Unscrew the controlling valve with the special wrench provided for this purpose, remove the controlling valve and controlling valve spring.

3. Remove the top cap and lift out the piston and cylinder liner. Remove the bottom cap and take out the main valve and main valve spring.

4. Clean all parts thoroughly. See that the main valve and the controlling valve seat properly and that the piston rings are free in their grooves. Clean the seat for the cylinder liner so that the cylinder liner does not project above the top flange of the main body. Clean the bore of the main valve guide and stem. If necessary, grind in the main valve seat and disk. Make certain that the stem of the controlling valve does not project above the diaphragm seat. The correct clearance between the controlling valve stem and the diaphragm is 0.001 to 0.002 inch.

When renewing gaskets and diaphragms of governors, be sure to use only parts made by the manufacturer of the governor. The diaphragm must be of the correct thickness and installed WITHOUT gaskets. Do not use graphite or other such substances on gaskets.

The control valve is another frequent cause of trouble in a Leslie pump governor. Steam passing through the control valve is continuously throttled; and the valve is subjected to considerable erosion (wire drawing). The control valve and control valve seat should be inspected frequently. When reassembling the control valve or installing a new one, it is very important to maintain the correct clearance between the control valve stem and the lower diaphragm. If the clearance is excessive, the lower diaphragm cannot fully open the control valve, and the pump capacity is reduced. If there is not enough clearance, the diaphragm will hold the control valve open and the pump cannot be stopped without closing the throttle valve. It is also necessary that there be no steam leakage through the control valve or under the control valve bushing because the leaking steam will hold the main valve open, allowing steam to flow to the turbine.

Faulty governor operation is sometimes due to the piston rings wearing grooves in the cylinder liner. The grooves will limit the travel of the main valve and reduce the capacity of the pump, or will cause failure of the governor. Whenever a constant pressure governor is disassembled, the liner should be carefully checked; and if it is grooved, it should be renewed.

Control valve springs should be inspected frequently. If the spring breaks or is weak, it cannot close the control valve, which allows a full flow of steam to the turbine.

AUTOMATIC CONTROL FOR MAIN FEED PUMPS

Main feed pumps on many ships are equipped with automatic controls that operate pneumatically. One type of control system for main feed pumps is discussed briefly in the following paragraphs. For additional information on this control system, and for information on main feed pump controls manufactured by other companies, consult the manufacturer's technical manual for the particular installation.

The Hagan differential pressure control system (fig. 6-4) for the control of main feed pumps measures the differential pressure across the feed water regulating valve and transmits a proportional pneumatic signal (air pressure) to the pneumatic hydraulic pressure controller that controls the speed of the pump. As an example of how this system works, let's assume that the normal feed pump discharge pressure to two 1200-psi boilers, 1-A and 1-B, is 1275 and that a pressure differential of 75 psi is normally maintained across the feed water regulating valve. Now let's open the feed water regulating valve wider to boiler 1-B, thus reducing the pressure differential across the valve from 75 psi to 50 psi. The Delta "P" transmitter for boiler 1-B measures this change in the pressure differential. The resulting unbalance of the transmitter causes an air valve to close, decreasing the pneumatic pressure to the 1-A boiler Delta "P" transmitter, which is in balance. (The Delta "P"

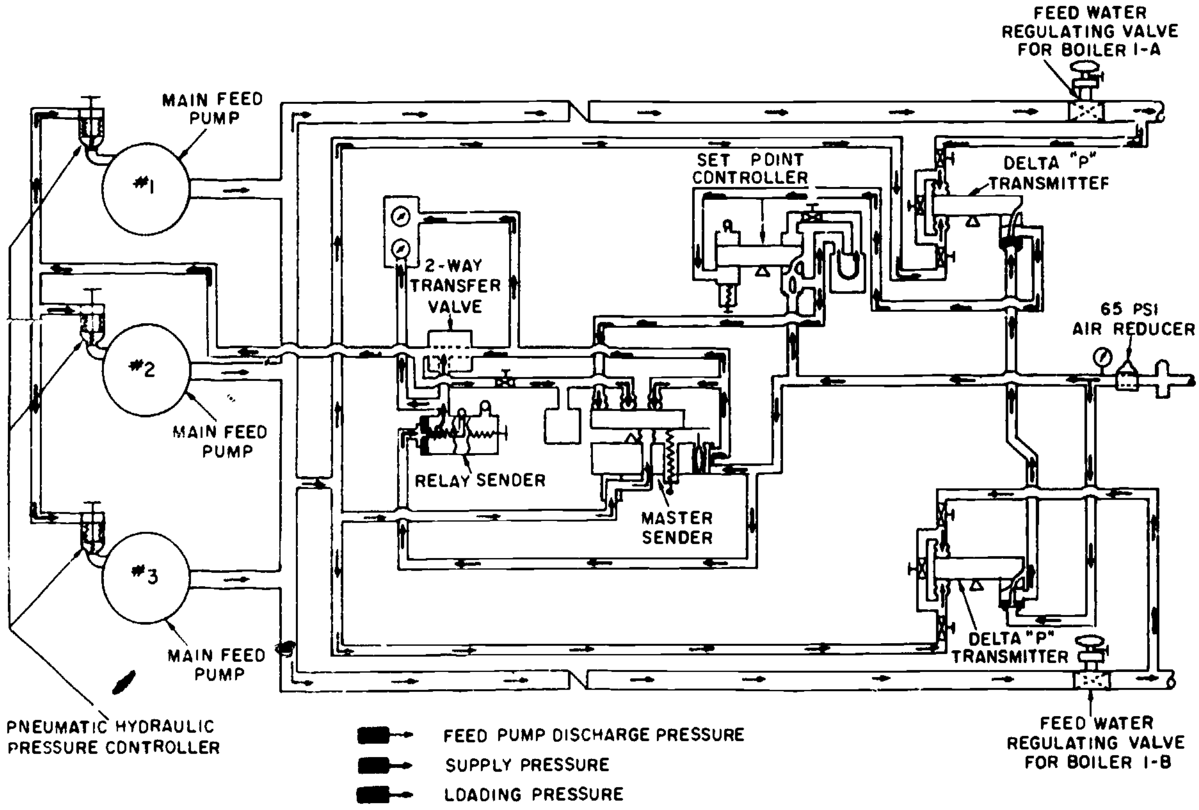


Figure 6-4.—Hagan pneumatic control system for main feed pumps.

transmitters are interconnected in such a way that when either boiler demands feed water the opening of the feed water regulating valve for that boiler will control the feed pumps.)

A proportional decrease in incoming pneumatic pressure to the 1-A boiler transmitter causes a proportional decrease in outgoing pneumatic pressure to the set point controller. A proportional decrease in input pneumatic pressure to the set point controller permits the spring to close the air valve, thus reducing the proportional pneumatic pressure to the master sender. This unbalances the master sender and causes the air valve to close, decreasing the proportional output loading pressure to the pneumatic hydraulic pressure controller (fig. 6-5). This action permits the bellows to contract and move upward, changing the compression of the loading spring and thus closing the oil cup valve. This action, in turn, permits oil pressure to build up, increasing the opening of the steam admission valves and thereby increasing the speed and discharge pressure of the main feed pump(s). As the water level in the boiler returns to normal, the feed water regulating valve closes down to maintain the proper feed flow. Since every change in position of the feed water regulating valve causes a change in the pressure drop across the valve, and since the Delta "P" transmitter is continuously measuring this pressure drop, the proportional output pneumatic pressure from the transmitter varies to control the speed of the main feed pump(s) in accordance with the demand for feed water.

SAFETY PRECAUTIONS FOR OPERATING PUMPS

1. Do not operate a pump with a defective overspeed trip, speed limiting governor, or speed regulating governor. If, in an emergency, a main feed pump or fire pump must be operated with a defective constant pressure governor, a man MUST be stationed at the throttle valve of the pump to regulate the discharge pressure.

2. Ensure that overspeed trips, where fitted, are set to shut off steam to the pump when the rated speed is exceeded by 10 percent.

3. See that speed limiting governors are set to limit the speed of the unit at not more than 105 percent of rated speed.

4. Check all pump control devices in accordance with the PMS and more often if so ordered by proper authority.

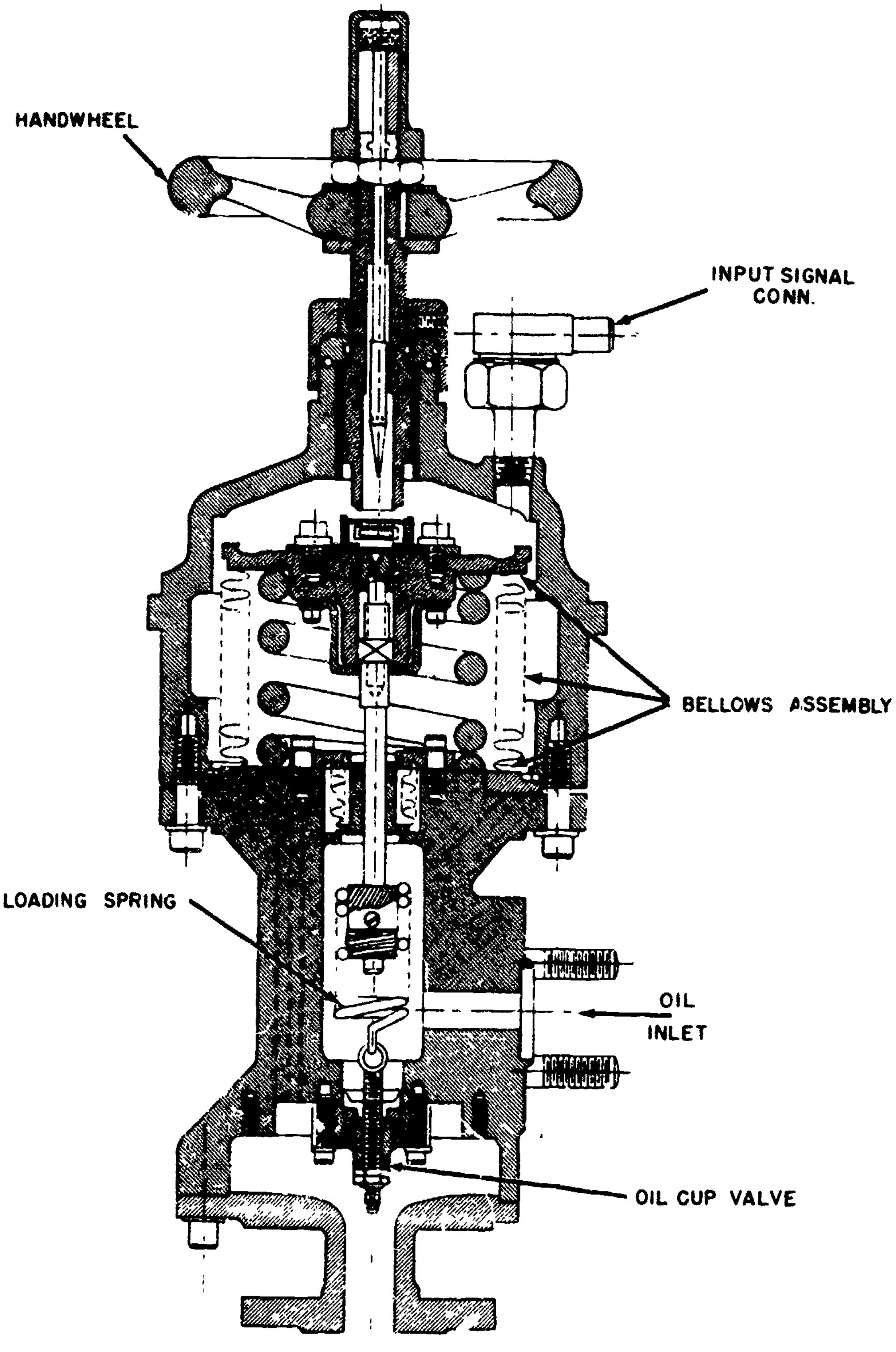


Figure 6-5.–Hagan hydraulic pressure controller.

CHAPTER 7

PIPING AND VALVES

Reasonable care must be given the various piping assemblies as well as the units connected to the piping. Unless the piping system is in good condition, the connected units of machinery cannot be operated efficiently and safely. Machinist's Mates need not be Hull Maintenance Technicians but they should be familiar with the recommended procedures and safety precautions to observe when maintaining piping systems. This chapter presents general information on the maintenance and repair of piping systems.

CARE OF PIPING SYSTEMS

The most important factor in maintaining piping systems in satisfactory condition is keeping joints, valves, and fittings tight. To ensure tightness it is necessary to make frequent tests and inspections.

When a ship is in operative status, piping should be tested at the frequency and test pressure specified in accordance with the Planned Maintenance System and the applicable equipment technical manual must be carried on for a period of time long enough to disclose any leaks or other defects in the system.

Where instruction books are available for piping systems and associated equipment, they should be followed. However, if the manufacturer's instructions are not available, NAVSHIPS Technical Manual should be referred to for details of piping maintenance.

MAINTENANCE AND INSPECTIONS

Maintaining the operational reliability of ships requires that all piping systems be in good operating condition; therefore, early detection and correction of piping defects are of the utmost importance. Fresh water, lube oil, fuel oil, aviation gas, jet fuel, and refrigerant gas are critical items—and any unnecessary loss of them must be avoided. Early correction of leaks, such as repair of faulty seats and disks, will reduce the amount of work, time, and material required for repairs. The following items are of extreme importance for the proper operation of valves and piping systems.

1. Piping systems should be surface inspected at regular intervals in accordance with the Planned Maintenance System in order to detect and eliminate leaks and to assure satisfactory protection from external corrosion.

2. NAVSHIPS Technical Manual and the manufacturer's technical manuals for component systems should be referred to for specific information on a particular piping system or component.

3. If specific instructions are not available, all piping in an operating status aboard ship should be tested quarterly under maximum operating pressure. In addition, a periodic hydrostatic test of 135 percent of the system designed pressure shall be applied to piping. The period between tests shall not exceed a maximum of five years; the test should be conducted prior to or during the early stages of a scheduled overhaul of the ship.

4. On ships in the reserve fleet, all piping not in use shall be kept thoroughly drained and should not be put under pressure for test purposes.

5. Drain holes which are provided in some systems to permit continuous drainage, should

be checked periodically to guard against their becoming plugged with dirt or other foreign matter.

6. Before pressurizing any portion of a piping system for operation or for test purposes. operate all valves except those which would pressurize the system from another source.

7. Ensure that all valves and equipment in, or connected to, the part of the piping system being tested are in the required position or condition. Admitting steam to an open boiler and opening injection or overboard valves to an open condenser are to be particularly guarded against.

8 Sudden stoppage or changes in the flow, velocity, or direction of liquids in piping will generate high pressure (water ram) and may possibly damage equipment Pumps should not be started when the discharge valve is open to a closed piping system. since the air present will be compressed and could result in damage to equipment.

9. Sudden temperature changes in a piping system can cause uneven contraction and expansion and can develop stresses which may cause material damage or failure. Rapid and excessive temperature changes are the primary cause of gasket failure.

10. Piping should never be used to provide footholds, handholds. or to support weight.

MARINE GROWTH

Rapid fouling of the firemains has been experienced on many ships, especially ships operating in tropical waters. To minimize fouling of the firemain and to prevent valves from being stuck open or closed, the following procedure is recommended:

1. Once each quarter. flush the firemain under full pressure. High velocity flow must be used to remove marine growth. The firemain system may be lined up to direct the flow of water from more than one pump in one end of the ship, through a section of the system, while discharging through an adequate number of weather deck fireplugs. This procedure may be changed to reverse the flow through the piping. Flushing should be accomplished in areas where the sea water is clean.

2. NAVSEA has approved a procedure for cleaning of firemain piping to remove scale and marine growth. This type cleaning can be accomplished by a naval shipyard or by an approved contractor. Acid cleaning is satisfactory and is economical because it can be done without dismantling the piping.

GASKETS

It is possible to achieve a tight seal between flanges of a flanged joint; however, this requires perfect mating of machined or ground surfaces. However, this method is costly, impractical, and generally unsatisfactory. To eliminate the necessity for producing and maintaining perfect joint-contact surfaces, relatively inexpensive and easily replacable gaskets are used as the sealing element. The seal is obtained by causing the gasket material to yield, or flow into the grooves or irregularities on the joint-contact surfaces.

For any flange, the type of gasket to be used will depend on several considerations: gasket characteristics, operating conditions, operating pressures, and mechanical features (bolting, shape of flange) of the flanged assembly. The selection of gasket for flanged joints shall be in accordance with MIL-STD-777. The appropriate chapter of NAVSHIPS Technical Manual contains information pertinent to the use of gasket materials.

Much of the trouble experienced with leaky joints in piping is due to poor alignment or to improper allowance for expansion. Either of these faults will throw excessive strain on joints. When the joints do not line up, the piping should be realigned so that the flanges or unions meet properly without being forced. In aligning piping, you must check the pipe supports adjacent to the joint to be made up to determine that the hangers are properly supporting the line. Correcting improper hanger support can be accomplished by loosening up on the supports and then adjusting them to carry their share of the load. In some instances, it may be necessary to reface the flanges. The piping sections must be in alignment so that the flange bolts can be inserted freely without forcing either the bolts or piping.

The most practical way to cut a full-faced gasket is to lay the sheet packing over the flange and mark the cutting limits by light blows with a ball-peen hammer. The bolt holes must be cut slightly larger than the bolts so that any tendency for the gasket to bulge along the bolt circle is eliminated. A gasket cutter should be used to cut gaskets that fit inside the bolt circle.

Before making up a gasketed joint, all bearing and sealing surfaces must be cleaned thoroughly. Surfaces must be checked for signs of damage from erosion or steam cutting. Flanges showing damage must be refaced or replaced. Bolts and nuts that show signs of corrosion or other imperfections should be reused. All bolts should be coated with an approved antiseize compound.

The first time a remade joint is put under pressure, it should be carefully inspected. In any sign of leakage is evident, all bolts should be tightened in small increments. If leakage continues after a new gasket has been used, an investigation for other possible causes should be made.

THREADED CONNECTIONS

Threaded connections have been used in piping systems in the past to a considerable extent. Experience gained in various operating tests revealed that these connections are susceptible to shock damage and to becoming loose due to vibration. Based on this, the general use of threaded connections is not permitted in new construction piping systems on ships built to Navy specifications.

UNIONS

Unions are designed to seal against leakage under operating conditions; they have a ground joint, metal-to-metal surface, or for high pressure air and oxygen service, they have an O-ring seal. The threaded union nut is required only to furnish mechanical strength for the joint, and does not have any of the fluid in the line acting on it. With a union joint, there is no reduction in pipe-wall thickness as there is with a threaded pipe joint.

When installing new lines of silver-brazed piping, not over 2 inches in diameter, sufficient union fittings and union fitting valves should be installed to facilitate repairs or alterations. Union joints may become loose due to vibration, and they should be checked for leakage at regular intervals.

FLARELESS FITTINGS

Flareless fittings (fig. 7-1) are suitable for use in hydraulic service and air service at a maximum operating pressure of 3000 psi and 250°F. Flareless fittings are installed where their use will conserve space, reduce weight, and reduce installation time and system cleaning time. Flareless fittings should not be used where there is insufficient space for proper tightening of the nuts, or where any equipment or piping must be removed for access to the fittings. One exception to this rule is a gageboard that is designed so that it may be removed as a unit for repairs or alterations. Flareless fittings should not be used where piping cannot be deflected easily to permit assembly and disassembly

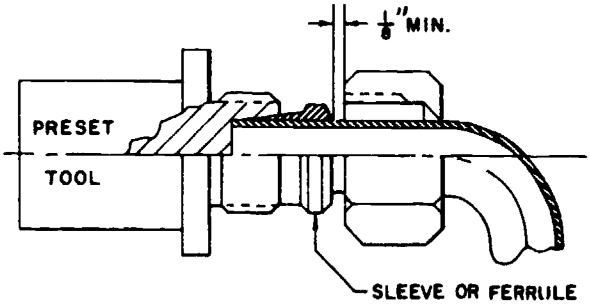
Before assembly, the tubing end must be square, concentric, and free of burrs. In order for the fitting to be effective, the cutting edge of the sleeve or ferrule must bite into the periphery of the tube; this is accomplished by presetting the ferrule.

VALVES

Valves, like other units of equipment, require proper care and maintenance. Valve troubles should be corrected as soon as possible.

CAUSES AND REMEDIES OF VALVE LEAKAGE

Internal valve leakage is generally a result of the disk and the seat failing to make a tight joint; and this failure may be due to one of the following causes:



96.34

Figure 7-1.—Typical flareless fitting.

1. Foreign substances (scale, dirt, waste, or heavy grease) are lodged on the seat in such a way that the disk cannot be seated. If the obstructing material cannot be blown through, the valve will have to be opened and cleaned out.

2. Scoring of the seat or disk has been caused by attempts to close the valve on scale or dirt, or by corrosion. If the damage is slight, the valve may be made tight by grinding the disk together with the seat; if the damage is extensive, a cut will have to be made on the disk, and the valve seat ring may have to be renewed before it is ground.

3. The disk may not seat properly because of a bent spindle guide, or a bent valve stem.

4. The valve body or disk may be too weak for the purpose for which it is used, causing distortion of the valve seat or disk under pressure.

5. In valves fitted with seat rings, leakage through the valve may occur as the result of leakage around the threads of the seat rings. To correct this defect, remove the seat ring, clean the threads, and remake the joint. It may be necessary to recut the threads in the valve and to renew the seat ring to secure tightness.

6. Leakage may be caused by a loose valve disk. When a valve disk comes loose from its stem, the cause is either failure of the securing device or corrosion. The first cause is infrequent in valves of good construction, and recurrence of the failure can be prevented by minor adjustments or by greater care in reassembling valve parts.

Corrosion of the valve stems occurs mostly to valves installed in salt water lines. Stems which have shown signs of corrosion should be inspected periodically so that replacement can be made before failure occurs. Replacements should be made with Monel stems. In order to prevent failure caused by corrosion, split pins used in valve disks in the waterlines should be of nickel-copper alloy instead of iron, steel, or brass.

When a valve is disassembled for repairs, several steps must be taken to ensure that the valve will be in proper condition when it is reassembled.

During disassembly every precaution should [be] taken to prevent damage to gasket and O-ring sealing surfaces, to seating surfaces, and to guiding surfaces. When the valve is disassembled, all parts should be thoroughly cleaned and inspected for excessive wear. Seating surfaces should be inspected to determine whether lapping, grinding, or machining is required to restore them to a tight fit. Gasket surfaces may be corroded or steam cut. The stem must be carefully checked (1) for straightness, (2) where the packing fits, and (3) at the threaded section.

If the seating surface has become badly corroded or is so deeply scored that excessive lapping would be required to remove the damaged areas, machining will be necessary. A reseating machine may be used. The proper size cutter must be used in the reseating machine and light cuts must be taken until the damaged areas are removed. If the seating surface is made from a metal that is too hard for a reseating machine to cut, the work will have to be done in a lathe.

After the machining is completed, the seating surfaces on metal-to-metal seated valves should be lapped to ensure that it will have the smoothest possible finish. The lap must be of the exact same size and shape as the valve disk so that the valve seating surface will be true. For more information on lapping valve seating surfaces, refer to the appropriate chapter of *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

An inspection should be made of the disk seating surface to determine whether lapping or machining will be required for reconditioning. If machining is required, light cuts should be taken until the damaged areas are removed. If excessive wear or severe pitting has taken place, the machining required to remove the damage may be extensive enough to warrant installing a new disk.

Reassemble the valve using new gaskets and packing. Be sure that all parts move freely as assembly progresses. Do not tighten the packing nut more than is necessary to prevent excessive leakage.

In any instance where new parts are required for a valve, the material must be the same as was in the original parts.

PRESSURE REDUCING VALVES

Several types of pressure reducing valves are installed on Navy ships. Some of the more common types are discussed in *Machinist's Mate 3 &*

2, NAVEDTRA 10524-D. Some of the maintenance procedures for these valves are discussed in the following paragraphs.

Pneumatic Reducing Valves

Pneumatic pressure-controlled reducing valves are pressure-balanced type valves which require a supply of air or gas under pressure for their motive force. The most probable causes of erratic operation of these valves are incorrect pressure in the loading dome or an accumulation of dirt or other foreign matter on the surface of the moving parts. The condition of improper loading pressure is easily remedied by increasing or decreasing the pressure of the gas or air to maintain the proper outlet pressure.

If the cause of improper operation is the presence of dirt or other foreign matter, the only remedy is to disassemble the valve and clean all parts. The valve may be disassembled in place, or removed from the piping and disassembled. When the valve is disassembled, clean all parts with an approved solvent and a bristle brush or soft cloth. NEVER USE AN ABRASIVE MATERIAL TO CLEAN VALVE PARTS. If the usual cleaning methods will not remove hardened deposits of oil or other foreign matter, the part may be cleaned by scraping with a sharp tool; extreme caution is necessary to prevent damage to the surface finishes. Particular attention must be given to cleaning all guide surfaces, to ensure that all moving parts will move freely without binding.

Another possible source of trouble is leakage around the seating surfaces of the disk and seat ring and the joint between the seat ring and the body. If leakage occurs at these points the valve will not operate properly. A careful inspection must be made of these surfaces and if leakage is present, the seat ring and disk may be reconditioned by lapping or grinding. If the joint between the seat ring and the body is leaking, a new seat ring must be installed.

All parts must be inspected for excessive wear; pay particular attention to the valve spring and the diaphragm spring. If either is broken or permanently set, a new spring must be installed.

When the valve is reassembled and installed, it should be tested by opening the outlet valve and cracking the inlet valve to thoroughly warm up the valve. The dome should be pressurized with air or gas to about 10 psig more than the desired outlet pressure.

Spring-Loaded Reducing Valves

Another type of reducing valve with which Machinist's Mates will be concerned, is the spring-loaded type that is installed in flushing and cooling water mains. It is of the single-seated direct-acting, diaphragm type and is illustrated in the appropriate chapter of *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

Failure of this type valve can usually be traced to one or more of the following causes:

1. Ruptured diaphragm.
2. Leakage through the disk seat or seat ring threads.
3. Ports stopped up with dirt or other foreign matter.
4. Grooves in the bore of the sleeve.
5. Cup leather leaking.

In the event the diaphragm ruptures, there will be no control over the flow of liquid through the valve. The diaphragm can be renewed without removing the valve from the piping system.

All tension must be taken off the adjusting spring, and then the diaphragm nuts can be removed from their bolts. Next the spring chamber can be lifted off the valve body. This provides access to the diaphragm, which can be removed, then a new one can be installed and the valve reassembled. The diaphragm should always be renewed when there is indication of deterioration.

Any time disassembly of the valve becomes necessary, all parts of the valve should be cleaned and inspected for excessive wear. Cleaning should be done with an approved solvent and a soft brush.

Particular attention should be given to cleaning the guide surfaces between the seat ring and ring guides and to the guide surfaces of the sleeve.

The seating surface of the seat ring should need little repair but in the event it is scored or otherwise damaged, it should be lapped in, using the same process as described for other valves. If the damage to the seating area is excessive or the bore is badly worn, a new seat ring should be installed.

If there are signs of deterioration of the disk seat, it should be renewed. If a new disk seat is not available, turning the seat over will provide a new seating surface; however, this should be considered as a temporary repair, and a new disk seat should be installed as soon as it is available.

If the cup leather shows signs of leaking or deterioration, it should be renewed. The bore of the sleeve should be inspected for excessive wear or corrosion. If there is excessive damage to the sleeve, it should be renewed. If the sleeve is only slightly damaged, the damage can be corrected by machining the surface in a lathe. Use extreme care to ensure that the bore is concentric, has a smooth finish, and is not enlarged to the extent that leakage will occur when the cup is installed.

RELIEF VALVES

Relief valves (fig. 7-2) are installed on piping and units of machinery where excessive pressure may build up and damage equipment or endanger personnel. Relief valves are adjusted to lift at the proper pressure by increasing or decreasing the compression of the spring.

Failure of the valve to function properly is usually due to an incorrect setting of the spring, leakage between the disk and seat, leakage around the threads of the seat ring, cocking of the disk or stem, or an accumulation of dirt or other foreign matter around the guiding parts

In most instances, relief valves may be disassembled in place or they can be removed from the piping, when repairs are necessary. The first step in disassembling a relief valve is to release all tension on the adjusting spring. This is accomplished by loosening the locknut and then loosening the adjusting screw. (Some relief valves are fitted with a test lever which must be removed before the spring tension can be released.) The top assembly can be removed by unscrewing the headbolt nuts and lifting the head from the body of the valve (depending on the construction of the valve). The disk can then be removed and the seating surfaces can be inspected. The seating surfaces can be reconditioned by lapping, grinding, or machining in the same manner as would be done with a globe valve.

All surfaces used for guide purposes should be inspected for burrs, galling, excessive wear, or other defects which may interfere with the free movement of the working parts. Parts which are worn excessively, or bent, or are in any way unfit for further service must be replaced. When replacing parts, those supplied by the manufacturer should be used, if obtainable.

When a relief valve has been overhauled, it is common practice to test it for leaks before installing it in the piping system or on a unit of machinery. It is far more practical to mount the valve on a test stand (if available) and conduct a hydrostatic test and then set the relieving pressure at the desired amount, than it is to test it after installation.

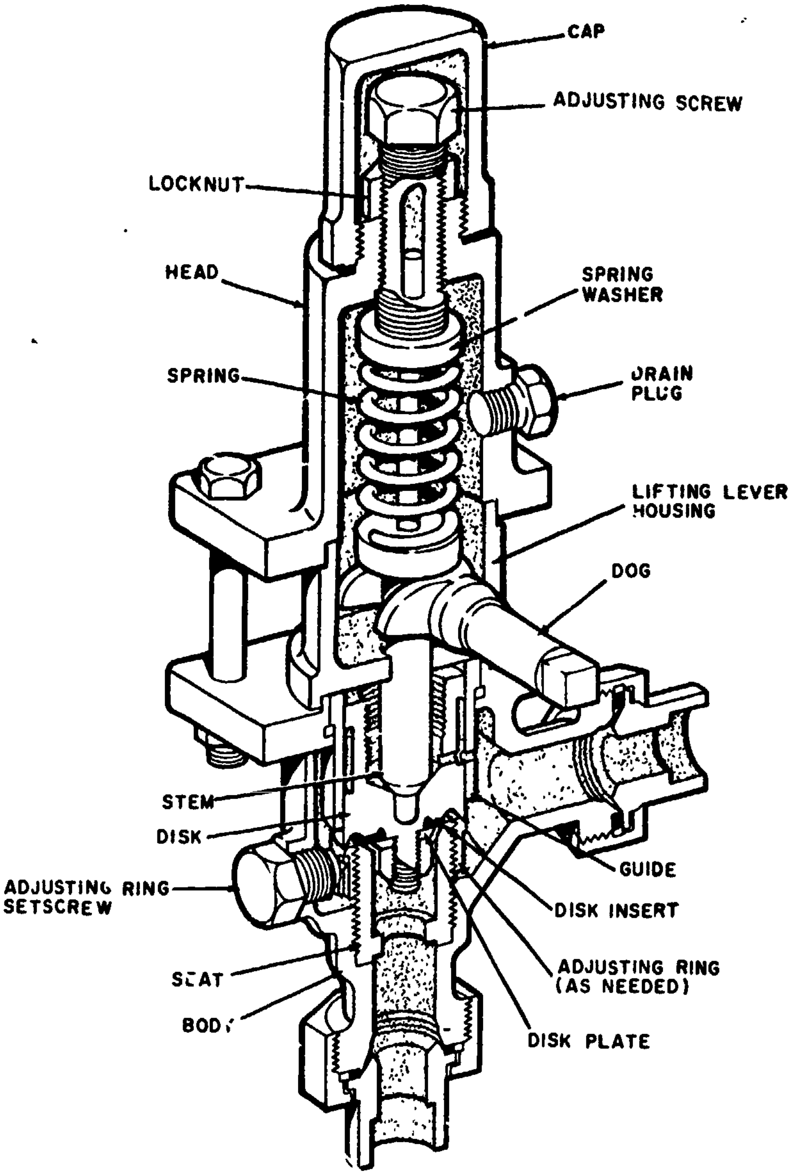
On some relief valves, an adjusting ring has been provided so that reseating pressure as well as the relieving pressure can be adjusted. The position of the ring may be raised or lowered in relation to the disk, by removing the adjusting ring setscrew and moving the ring to the desired position. Raising the ring will increase the blowdown period and lowering the ring will decrease the blowdown period.

DIAPHRAGM CONTROL VALVES WITH AIR–OPERATED PILOTS

Diaphragm control valves with air-operated control pilots are being used increasingly on newer ships for various pressure-control applications. These valves and pilots are available in several basic designs to meet different requirements. The principles of operation of this type control valve are explained in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

Many of these air-operated control valves are constructed with hand wheels for manual operation in the event of a loss of air pressure or a malfunction of the control system. Depending on the specific system criteria these valves and control systems are designed to fail in one of three positions upon a loss of air pressure. They will fail in the open position, closed position, or in the position they are presently in until actuated.

The manufacturer's instruction manual should always be consulted for information on any repair or calibration of air-operated control systems.



96.52

Figure 7-2.—Relief valve.

HYDRAULIC VALVE MAINTENANCE

Valves are used in hydraulic systems to control the rate of flow, the direction, and the pressure of the fluid. Hydraulic valves are usually named or identified by the function, capacity (size), and pressure rating. In some instances the identity of the valve may reflect a feature of its construction such as a needle valve (characterized by a long tapered valving element) or a servo valve (basically a variation of an electrically operated directional valve, using a small electrical signal to control a relatively large flow of fluid). Maintenance of the hydraulic valves is mainly concerned with checking that all of the parts are clean and in good condition. Any imperfections of the parts should be corrected as soon as noticed. Leakage through the valve will increase quite rapidly due to erosion. Maintenance and repair procedures will be in accordance with the Planned Maintenance System, and applicable equipment technical manuals.

The following precautions are to be observed when performing maintenance on hydraulic valves.

1. Perform all maintenance in a clean, uncluttered area.
2. Do not reverse the ends of the spool and sleeve after removing them from the valve body. (Each spool is matched to its sleeve by the manufacturer.)
3. Before removing a spool from its sleeve, matchmark the ends with marking pencil, chalk, or tape. DO NOT matchmark with a prick punch.
4. While the spool and sleeve are out of the body, keep them wrapped in lint free cloths to protect their finished surfaces.
5. Never replace only a spool or a sleeve. If one piece requires replacement, replace both pieces with a spare matched set.
6. Never lap or grind a spool or sleeve.
7. Clean parts of hydraulic valves with lint free cloths.
8. DO NOT use compressed air to clean out the ports or bore of a hydraulic valve. Particles in the air stream would abrade the seating surfaces.

CONSTANT PRESSURE GOVERNOR MAINTENANCE

The principles of operation of constant pressure governors are explained in the appropriate chapter of *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

The following paragraphs deal with maintenance of these governors. For more complete details on operation and maintenance of constant pressure governors, consult the manufacturer's technical manual.

The most common cause of improper operation of constant pressure governors in dirt or other foreign matter being carried with the ...m into the governor and interfering with the operation of the moving parts. The only remedy is to disassemble the governor and thoroughly clean all parts.

Failure of the governor to properly regulate the pump discharge pressure may also be caused by one or more of the following reasons:

1. Leakage around the seating surfaces of the control valve, the main valve, or the threads of their respective seat rings.
2. A main valve spring or a controlling valve spring that is broken, is weak, or that has taken a permanent set.
3. A broken, cracked, or excessively deformed diaphragm.
4. Improper adjustment of the needle valve.
5. Too little or too great a clearance between the control valve and its diaphragm.
6. Clogged ports in the diaphragm chamber.
7. Binding of any moving parts.

This is not a complete list of reasons for failure of constant pressure governors, but it does cover the most common causes.

Removal of Foreign Matter

When a constant pressure governor acts sluggishly or erratically because dirt or other foreign matter is interfering with the free movement of working parts, the governor must be completely disassembled, and all parts cleaned. The manufacturer's technical manual gives a step-by-step procedure for disassembly. Extreme care must be taken in the removal of all parts, and in the cleaning. The parts may be cleaned with an approved solvent and a soft brush. If this cleaning method fails to remove hardened deposits, a sharpened tool may be used with extreme caution.

Cylinder Liner

Particular attention should be given to cleaning the seat for the cylinder liner. The cylinder liner must fit properly to prevent it from projecting above the body flange. The bore of the main valve guide must also be carefully cleaned. As each part is cleaned, it should be carefully inspected for excessive wear. If it is necessary to renew parts, use only parts furnished by the manufacturer.

Control and Main Valves

If there is leakage through the control valve or its bushing, steam will flow to the top of the operating piston, opening the main valve, and holding it open, even though there is no tension on the adjusting spring. The main valve must be able to close off completely or else the governor cannot operate properly. The only remedy for this situation is to disassemble the governor and stop the steam leakage. In most instances, the control valve must be renewed. If the leakage is through the bottom of the bushing and its seat, the seat must be lapped. A cast iron lap is best for this type of work.

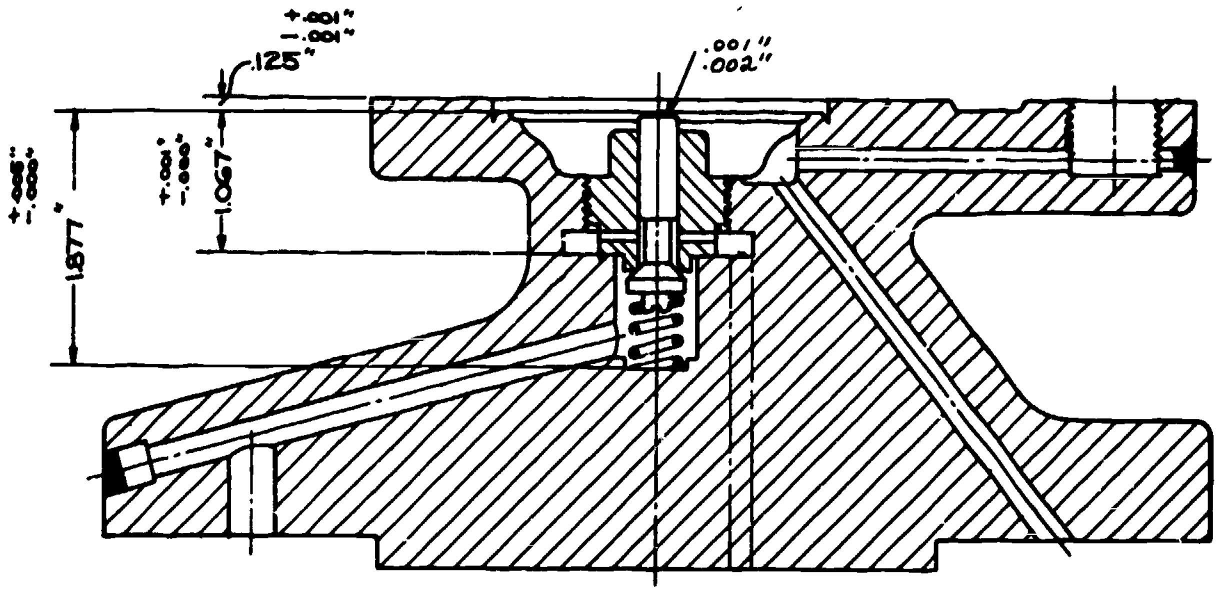
The lap should be rotated through a small angle of rotation, lifted from the work occasionally, and moved to a new position as the work progresses. This will ensure that the lap will slowly and gradually rotate around the entire seat circle. Do not bear down heavily on the handle of the lap, and take particular care not to bear sideways on the lap. Replace the compound often, using only clean compound. If the lap should develop a groove or cut, redress the lap. Lapping should never be continued longer than is necessary to remove all damaged areas.

When you are installing the control valve and its bushing, remember that the joint between the bottom of the bushing and its seat is a metal-to-metal contact. The bushing must be installed tightly; and when it is all the way down, the wrench should be tapped lightly with a hammer, to ensure a steamtight joint.

When the controlling valve is installed, the clearance between the top of the valve stem and the diaphragm must be checked. It is absolutely mandatory that this clearance be between .001 and .002 inch (fig. 7-3). If the clearance is less than .001 inch, the diaphragm will hold the control valve open, allowing steam to flow to the main valve at any time the throttle valve is open. If the clearance is more than .002 inch, the diaphragm will not fully open the control valve - which means that the main valve cannot open fully, and the unit cannot be brought up to full speed and capacity.

When the main valve seating area is damaged, it must be lapped in by the same process. ALWAYS lap in the main valve with the piston in the cylinder liner to ensure perfect centering.

If the damage to the seating surfaces is excessive, new parts must be installed; use only parts supplied by the manufacturer, if available.



96.35

Figure 7-3.—Important points in cleaning and reassembling a top cap assembly.

TOP CAP

If the top flange of the top cap becomes damaged, extreme care must be taken in machining it. The manufacturer's technical manual must be consulted for the correct clearances. (See fig. 7-3.)

All seating surfaces must be square with the axis of the control valve seat threads and must have the smoothest possible finish. Before the reassembly is started, all ports in the top cap and diaphragm chamber must be free of dirt or other foreign matter. A check should be made to ensure that the piston rings are free in their grooves. The cylinder liner must be smooth and free of grooves, pits, or rust.

When installing the cylinder liner, make certain that the top of the liner does not extend above the top of the valve body. The piston must work freely in the liner: if there is binding, the governor will not operate satisfactorily. The controlling valve spring and the main valve spring should be renewed if they are weak, broken, or corroded, or if they have taken a permanent set. If necessary, renew all diaphragms; if the old diaphragms are used, they should be installed in their original position; do not reverse.

The instructions in the manufacturer's technical manual should be followed in reassembling the governor. All clearances must be as designed if the governor is to operate satisfactorily. Each moving part must be carefully checked to ensure freedom of movement.

When the governor is reassembled, it should be tested as soon as possible so that corrections, if necessary, can be made.

PREVENTION OF POLLUTION OF COASTAL WATERS

The Navy's problems are not those generally caused by massive oil spills, but by the detrimental small spills in harbors which are caused by leaks in systems; overflows through vent pipes on ships, fuel line parting during oil transfers and recovering operations, and human errors. Cleaning up those oil spills is time consuming, difficult, and costly. Such spills often result in claims against the Government; and they create a serious fire hazard, are harmful to fish, shellfish and wild life; cause damage to watercraft; deny unrestricted use of bathing beaches and other private property; can contaminate water supply systems; and be aesthetically displeasing.

OIL POLLUTION

On naval ships, means are provided for separating oil from bilge water before the water is pumped overboard. In most cases, the means of separation consist of settling tank properly piped for handling the oil and bilge water. Whether settling tanks or mechanical separators are used, it is desirable to maintain the percentage of oil in the water discharge at less than 0.01 percent.

A ship under way can discharge water containing up to 0.01 percent of oil, even in coastal waters, without harmful consequences. Since the oil is spread out over a wide area in an extremely thin layer, invisible from the deck, and under the agitation of wind and wave, it is susceptible to disintegration in a short time by oxidation, evaporation, and absorption of salts from the water, forming pellets or globules heavy enough to sink.

When ships are at anchor or docked in harbors or rivers, the percentage of oil content in the effluent water ceases to be a suitable determinant of the purity of the water, since the actual quantity of oil discharged is the important factor. When conditions are not favorable to the dissipation of the resultant oil film, the effluent should be as nearly free as possible of oil.

When oil is mixed with water, it appears as free or floating oil, suspended oil, or emulsified oil. Free oil separates out in from two to four minutes. Suspended oil can be separated only after a period, approximately four hours.

In ships which use oil tanks for water ballast, each tank serves as a settling tank for most of the water and oil in the tank. About 90 percent of the water contained in a tank usually may be pumped directly overboard through the low suction, making it necessary to send only the last

10 percent through separators or to special holding tanks.

CHROMATE POLLUTION

Chromate solutions SHALL NOT be discharged within three miles of any shore.

Operations in inland, coastal and harbor waters involving the discharge of chromate solutions shall not be conducted unless the chromate solution can be discharged into a barge or other suitable receptacle which will not permit pollution of the surrounding water.

Chapter 8

DISTILLING PLANTS

This chapter deals with operating, troubleshooting, and repair of submerged tube and flash type distilling plants that are being used by the Navy. For more detailed information than is provided by this training manual, consult the manufacturer's technical manual for the particular type of plant on your ship.

SUBMERGED TUBE PLANTS

Low pressure, submerged tube plants will vary for different ships, but the abnormal operating conditions and the maintenance procedures are basically the same. In almost all instances, the personnel who stand watches on distilling plants are also responsible for the maintenance of the plants. This gives ample opportunity to detect abnormal operating conditions before such conditions reach advanced stages. When operating troubles occur, it is the responsibility of the MM1 or MMC to locate the trouble and to ma·· the necessary adjustments or repairs.

GENERAL INSTRUCTIONS

Steady operating conditions are essential for satisfactory results. Except under emergency conditions, no plant should be forced beyond its rated capacity, because higher steam pressures will be required and the resulting higher temperatures will cause more rapid scaling of the evaporator tubes.

In operation, the various elements of any plant are interdependent due to the heat and fluid balances throughout the plant. Adjustment of any one control can produce widespread effects on these balances. For example, an increase ·· the feed to the first effect will raise the liquid level in the first effect. More heat will be required to raise the feed to the boiling point, so that less heat will be available for evaporation in the first-effect shell and a smaller amount of heat will flow to the second-effect tube nest. These changes would work out to a new balanced condition, but other adjustments would be required to make the new balance satisfactory. Under such circumstances, overcontrolling can cause many readjustments to be necessary. The operator will always find it is better to make adjustments singly and in small increments, allowing enough time between each adjustment for the conditions to become steady.

CAUSES OF LOW PLANT OUTPUT

Failure to obtain full rated capacity is one of the most frequent troubles encountered during operation of a distilling plant. The trouble may be very difficult to remedy since it may result from a combination of things. The various factors which promote full output of the distilling plant are as follows:

1. Proper steam pressure above the orifice.
2. Highest possible vacuum in the first-effect tube nest.
   a. No air leaks.
   b. Proper water levels in the evaporator shells.
   c. Evaporator tube nests continuously vented.
   d. Evaporator tube nests reasonably clean.
   (1) Continuous feed treatment and periodic chill-shocking.
   (2) Tubes mechanically cleaned when necessary.

e. Density of brine overboard not over 1.5/32.

(1) Overboard piping reasonably clean.

(2) Proper valve settings.

(3) Proper operation of brine pump (clean piping and strainers, proper speed and diretion of rotation, pump properly vented, gland properly vented, gland properly packed and sealed, no air leaks in piping).

f. Tube nests properly drained.

(1) Proper operation of all drain regulators.

(2) Proper operation of the tube nest drain pump.

3. Highest possible vacuum in the last-effect shell.

a. No air leaks.

b. Proper air ejector operation.

(1) Clean nozzle and strainer.

(2) Steam at the required quality and quantity.

c. Ample flow of circulating water.

(1) Clean strainer, pipeline, and tubes.

(2) Proper valve settings.

(3) Proper operation of the circulating pump.

d. Effective surface in the distilling condenser.

(1) No undue deposits inside the tubes.

(2) Proper venting of the condenser tubes.

(3) Proper operation of the condensate pump.

Steam Pressure

A distilling plant cannot maintain its full output unless it is supplied with dry steam at the designed pressure. The orifices supplied are designed to pass the proper amount of steam to ensure designed plant output with a pressure of about 5 psig above the orifice. The orifice should be inspected annually. At this time the orifice should be measured and the reading compared with the figure stamped on the plate. If necessary, the orifice should be renewed.

If the steam pressure above the orifice varies, the source of trouble should be located and corrected. First the weight-loaded regulating valve should be checked, and then the pressure reducing valve (if installed), to determine whether or not the valve is operating properly. If it is functioning properly and the pressure cannot be maintained above the orifice, an insufficient amount ot steam is being supplied to the plant.

The auxiliary exhaust steam supply for the distilling plants, after passing through the regulating valve, is usually slightly superheated, due to the pressure drop through the reducing valve and orifice plate. A small amount of superheat has little or no effect on operation or scale formation; however, if it is necessary to use live steam, the installed desuperheater spray connection should be used to control the superheat. The water for desuperheating must be taken from the boiler feed system, preferably from the first-effect tube nest drain pump. Water for desuperheating must never be taken directly from the fresh water distilled by the distilling plant.

Fluctuations in the first effect generating steam pressure and temperature cause fluctuations of pressure and temperature throughout the entire plant. The fluctuations may cause priming, with increased salinity of the distillate, as well as erratic water levels in the shells. Proper operation of automatic pressure regulators in the steam supply line will eliminate fluctuation of the pressure in the first-effect heat exchanger.

First-Effect Tube Nest Vacuum

The pressure maintained in the first-effect tube must be within the range of from 16 inches of mercury, with clean tubes, to 1 to 2 inches of mercury as scale forms. The output of a submerged tube type distilling plant is not greatly reduced until the deposits on the tubes have caused the vacuum to drop to about atmospheric pressure. When the first-effect tube nest vacuum is lost entirely, the reduction in output becomes very great. Assuming the reduction in vacuum is due to scale and not to improper operating conditions, the tubes must be cleaned.

Keeping the vacuum in the first-effect tube nest as high as possible helps keep scale formation to a minimum, enabling the plant to operate at full capacity.

A vacuum reduction resulting from any factor other than deposits on tube surfaces should be corrected. This will reduce deposits and greatly prolong the interval of time between cleanings. The primary factors affecting the first-effect tube nest vacuum are: air leakage, low water level in the evaporator shells, improper venting of the evaporator shells, scale or other deposits on the tubes, and improper draining of the evaporator tube nests.

Loss of vacuum resulting from deposits on evaporator tubes should be gradual. Under normal conditions, there will be no large change of vacuum for any one day's operation. A sudden drop in vacuum can be traced to causes other than scale deposits.

The generating steam circuit operates under vacuum and is subject to air leaks. Leaks from the steam side of the first-effect tube nest to the first-effect shell space will cause losses of capacity and economy. Air leaks from the atmosphere into the generating steam line (downstream from the orifice plate), the first-effect tube nest front header, and the first-effect tube nest drain piping will cause a loss of vacuum and capacity. Air leaks in this part of the distilling plant may be less noticeable than air or water leaks elsewhere because the effect on the plant is similar to the scaling of the tube surfaces.

Proper Water Levels

A reduced first-effect tube nest vacuum can result from too low a water level in any evaporator shell. On older plants, the water levels are controlled by manually regulating the feed valves. On newer ships, the water levels are automatically controlled by weir type feed regulators. Inability to feed the first effect is usually due to scale deposits in the sea-water sides of the air ejector condenser and the vapor feed heater, or to obstructions in the feed line. Inability to feed second or third effects is due to air leakage or heavy scale deposits in the feed lines between the effects. It is important that the gage glass and the gage glass fittings be kept free of scale or false water level indications will result. Air leaks around the gage glass will also result in false level indications in the gage glass.

Once the distilling plant is in operation, the feeding must be maintained at a steady rate. Sudden rising of the water levels or too high a water level will cause carry over of small particles of brine with the vapor (priming). The level of water in the shell must be carried at the highest level that can be held and still prevent the ...ing over of salt water particles with the fresh water vapor, because scale will form rapidly on exposed tube surfaces.

The pressure differential between the first and second effects permits the second-effect feed to be discharged into the second-effect shell. A partial or total loss of pressure differential indicates that air leaks have occurred between the first and second-effect shells in the two-effect distilling plants. Large air leaks between the first effect and second effects can be readily detected because the vacuum gage for the first effect will read approximately the same as the vacuum gage for the second effect. Large air leaks of this type will disrupt the operation of the plant and must be located and repaired before the plant will operate properly.

Improper Venting of Evaporator Tube Nests

Improper venting of the evaporator tube nests causes either an accumulation of air in the tubes, with a loss of capacity, or an excessive loss of tube nest steam to the distilling condenser, with loss of economy. Troubles of this type usually result from improper operation rather than from material failures.

Scale Deposits on Evaporator Tubes

Until 1958, scale deposits on evaporator tubes had been one of the more serious operating difficulties. In 1958, a new compound was authorized for treatment of evaporator feed water. The new compound PD-8 evaporator treatment is far superior to the cornstarch-boiler compound formerly used. For details on PD-8 and its use, refer to the applicable chapter in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

Last-Effect Shell Vacuum

Most manufacturers' technical manuals indicate that a vacuum of approximately 26 inches of mercury should be obtained in the last-effect shell when the temperature of the sea water is 85°F, and that the vacuum should be higher when the sea water is colder. Failure to obtain a vacuum of 26 inches of mercury, or more, can generally be traced to one of the following factors: air leaks, improper operation of air ejectors, insufficient flow of sea water, and ineffective use of heat transfer surface in the distilling condenser.

Test for Air Leaks

The importance of eliminating air leaks cannot be overemphasized. Many distilling plant troubles are direct results of air leaks. Air leaks in the shells of distilling plants cause a loss of vacuum and capacity. Extreme care must be taken in making up joints and in keeping them tight. Joints should be periodically tested under pressure for leaks.

There are several methods by which tests can be made for air leaks in the tube nests, heat exchangers, shells, and the piping systems of the distilling plant. When the plant is in operation, a candleflame can be used to test all joints and parts under vacuum. With the plant secured, air pressure tests or a soapsuds test can be used on the various component parts of the distilling plant. The manufacturer's technical manual describes how the various parts of the plant can be isolated and placed under air pressure.

Air leakage may also be detected by hydrostatically testing the various parts of the plant. When performing air tests or hydrostatic tests, precautions should be taken not to exceed the maximum limit of the test pressures specified by the manufacturer.

Testing for Salt Water Leaks

If a leak is detected in a heat exchanger, the defective tube(s) should be located by means of an air test or a hydrostatic test, in accordance with the recommended procedure in the manufacturer's instructions. Blueprints should also be used to study the construction details of the individual heat exchanger.

As soon as a leaky tube has been located, it should be plugged at both ends. Special composition plugs, which are provided in the allowance repair parts, should be used.

Since plugging the tubes reduces the amount of heating surface, the heat exchanger will fail to give satisfactory performance after a number of tubes have been plugged. It will then become necessary to retube the heat exchanger. Under normal conditions, this work should be accomplished by a naval shipyard or tender. However, repair parts and a number of special tools are included in the Ship's Allowance List, so that emergency repairs can be made to the heat exchangers and to other parts of the distilling plant.

To find which of the tubes within a REMOVABLE TUBE BUNDLE is leaking, it is necessary to test the individual bundles hydrostatically. If the leak is in a removable bundle (vapor feed heaters when within an evaporator shell, evaporator tube nests, distilling condensers on Soloshell end-pull plants), the bundle must be withdrawn and a hydrostatic test at full pressure (50 psi) must be applied on the tube side.

If a leak occurs in a NONREMOVABLE TUBE BUNDLE (distillate coolers, air ejectors condenser, external vapor feed heaters), the tube nest covers must be removed, and the full test pressure (50 psi) applied on the shell side of the unit.

If a nonremovable distillate condenser bundle is within an evaporator shell, the tube nest covers must be removed and a full test pressure of 30 psi should be applied to the evaporator shell.

If the distilling condenser is fitted with a diaphragm-type (Goubert) expansion joint, a test ring will be required to replace the tube nest cover for testing.

Air Ejector Operation

In operation, air ejectors require little attention. However, the following points should be noted.

1. The steam pressure at the nozzle inlet must not be less than that for which the ejector is designed (and which is stamped on the nameplate). There may be a substantial pressure drop in the steam line, and it may be necessary to carry a higher pressure on the gage. Pressures at the air ejector nozzle may be 10 to 15 psig higher than the minimum specified by the manufacturer.

2. The primary causes of air ejector trouble are low steam pressure, wet steam, an obstructed nozzle, or a clogged steam strainer. Such trouble is indicated by failure to obtain or to maintain the required vacuum. If the trouble is due to low

steam pressure or to wet steam, it will be necessary to increase the steam pressure or to provide suitable drainage, either by installing a trap or by manual means. If the nozzle or steam strainer is clogged, it must be removed and cleaned. Most plants are provided with two sets of air ejectors; this permits the use of the plant on one unit while the second is available for cleaning or repair. However, some of the latest plants have only one set of air ejectors.

When it becomes necessary to clean air ejector nozzles, they can be cleaned with the special nozzle reamers furnished each ship for this purpose. Sharp-edged tools should never be used for cleaning nozzles. The nozzle surfaces will be damaged and the efficiency of the air ejectors will be impaired.

A procedure for testing air ejectors can be found in the manufacturer's technical manual. In general, the same maintenance procedures should be followed for distilling plant air ejectors as for air ejectors for main condensers.

The air ejector strainer is usually an integral part of the air ejector inlet. It should be inspected and cleaned in accordance with the Planned Maintenance System. When a new plant is first put into operation, the strainer may require cleaning every day or even more frequently. Failure to keep the strainer clean will cause a reduced or fluctuating vacuum. In the event a strainer or a nozzle becomes damaged, it should always be replaced with a new one.

Insufficient Circulating Water

An insufficient flow of circulating water is indicated if the temperature of the water rises more than 20°F in passing through the condensing section of the distiller condenser. The last-effect shell pressure is directly dependent upon the distiller condenser vacuum. The vacuum is dependent upon the temperature and quantity of the circulating water, and the proper operation of the air ejectors. Too low an overboard discharge temperature of the distiller condenser circulating water is accompanied by efficiency losses in the distilling plant. The overboard discharge temperature should be kept as high as possible, without exceeding the desired 20°F temperature rise through the distiller condenser. In addition, limiting the quantity of circulating water tends to prolong the service life of the tubes and tube sheets. When troubles occur which do not result from improper operating procedures, an inspection should be made of the condenser circulating water system to determine the cause of faulty operation.

Preventive maintenance procedures should be carried out to ensure that the circulating water pump is maintained in good material condition. The maintenance and repair procedures for this pump are similar to those for the other pumps of the plant.

Routine procedures should be carried out to ensure the proper setting and maintenance of the back-pressure regulating valve. If this valve is not functioning properly, the valve should be disassembled, the valve parts replaced, and repairs to the valve made (as found necessary), before its faulty operation interferes with the operation of the distilling plant.

To ensure that the condenser circulating water system is clean and free from scale and foreign matter, the piping should be inspected at regular intervals. The operators of the distilling plant should inspect and clean the strainers to prevent accumulations of foreign matter from interfering with the proper operation of the plant in accordance with the Planned Maintenance System.

Improper Drainage

Failure of the distilling plant to produce designed output when the pressure above the orifice is 5 psig and the first-effect tube nest vacuum is several inches of mercury always indicates improper drainage of the distiller condenser or of one of the evaporator tube nests subsequent to the first effect. Complete flooding of the flash chamber gage glass is also a positive indication of improper draining of the condenser, but the fact that the level appears to be in the gage glass or below, is not necessarily an indication of improper drainage because air leaks at the gage glass fittings may indicate a false liquid level.

A temperature difference of more than 5°F to 10°F between the last-effect shell temperature and the temperature of the distillate at the distillate cooler inlet is another indication of improper drainage; however, the fact that the temperature difference is within the proper range does not necessarily indicate proper drainage.

Scale deposits are unlikely to form in the distilling condenser tubes if the plant is properly operated and a full flow of circulating water is maintained. However, if scale deposits do occur, the tubes must be cleaned.

Venting of the vapor side of the distiller condenser is continuously accomplished by the air ejector. Venting of the salt water side of this and other units of the distilling plant need not be continuous. While starting the plant and once every watch thereafter, the vents on all salt water heads should be opened until all air is expelled and a solid stream of water appears, then the vents should be closed.

Constant Brine Density

The concentration of brine in the evaporators, to a certain extent, has a direct bearing on the quality of the distillate, and since varying quantities of brine discharged overboard may affect the operating conditions, the quantity of brine discharged and the brine density must be kept as constant as possible.

If the brine concentration is too low, there will be a loss in capacity and economy. If the brine concentration is too high, there will be an increase in the rate of scaling of the evaporator heating surfaces, and the quality of the distillate will be impaired.

The brine density, which should never exceed 1.5/32, is dependent mainly on the quantity of brine pumped overboard and the amount of fresh water being produced. The density must be checked frequently during each watch and adjusted to the required density. On older distilling plants the brine density is adjusted by means of a hand-controlled valve located in the discharge line of the brine overboard pump. In plants equipped with wire control valves and in basket type plants, the brine density is controlled by adjusting the first-effect feed valve. Increasing the rate of feed decreases the brine density, and decreasing the rate of feed increases the brine density

Frequent changes of brine density have a tendency to disrupt steady performance of the plant, therefore, only very small changes should be made. The proper setting for a specific plant should be learned from experience; and this setting should be maintained as practicable.

Use of the Salinometer

The salinometer is an instrument (on the principle of a float) for measuring the degree of salinity or the concentration of the brine. It is a hollow, metal vessel weighted at the bottom, and having a projecting stem which is graduated in four scales to read the salinity for various temperatures of the brine. The graduations are marked in thirty-seconds. When the salinity of a sample of brine is to be measured, the temperature of the sample should be brought to a temperature corresponding to that of one of the scales on the instrument in order that an accurate reading may be obtained. The accuracy of the salinometer should be checked occasionally by placing it in distilled water; if it is accurate, it should sink to the zero mark on the scale corresponding to the temperature of the water.

A pot is provided for holding the sample of brine. The pot must be amply deep so that there is no danger of breaking the bottom of the salinometer when it is placed in the pot. To use the salinometer proceed as follows:

1. Draw off a sample of brine, from the test cocks on the discharge side of the brine pump, then insert the thermometer into the sample.
2. Allow the sample to cool to the temperature of one of the scale temperatures.
3. Put the salinometer in the pot and read the degree of salinity.
4. Remove the salinometer and wipe off all moisture since accumulations of salt or dirt will result in false readings.

FLASH TYPE DISTILLING UNITS

Many ships built since World War II are equipped with flash type distilling plants. Information on principles of operation of this type distilling plant can be found in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D. This training manual contains information on maintenance procedures, but for details on any specific plant, consult the manufacturer's technical manual.

The flash type evaporator, like all distilling plants, removes salts and other impurities from raw sea water by the process of evaporation and condensation. This is accomplished by boiling the water to convert it to steam and condensing this steam to form distilled water. The flash evaporator is different from other distilling plants, because evaporation takes place at temperatures well below the normal boiling point of water and without the use of submerged heat transfer surfaces.

In the flash type distilling plant, the temperature of the water is never raised beyond 175°F, and is only raised to this temperature within the last pass of tubes of the salt water heater. Flash evaporation takes place at temperatures as low as 104°F. In addition, no boiling occurs on heat transfer tube surfaces, a. a result this greatly reduces scale formation and prolongs operation at maximum efficiency.

The term "flash evaporation" means that water is converted to steam as it enters an evaporating chamber, without further addition of heat. Flashing at low temperatures is possible only when a vacuum is maintained in the chamber, since the boiling point of water decreases as the pressure in the chamber is reduced. As in other methods of distillation, a portion of the water remains behind in the evaporating chamber and is taken off as a concentrated waste (brine).

PRINCIPAL COMPONENTS

The unit discussed in this section is a five stage plant in which feed water is flashed to vapor in five evaporator stages at successively lower pressures.

Connections, or passages, that exist between evaporator stages are the feed water and distillate loop seals, which permit the flow of feed water and distillate from stage to stage while preserving the varying degrees of vacuum in each stage.

The condensers are mounted on top of each stage between the front and rear water boxes. Feed water flows through the tubes in six passes, entering at the lowest tubes at the front of the condenser, reversing direction at the water boxes three times and leaving at the top of the tubes in condenser. Each condenser has a pet cock for venting entrained air or noncondensable gases.

The evaporator stages become larger in the direction of reduced pressure. The feed water loop seals which extend from the bottom of evaporator stage one through four are visible as cylinders. An evaporator drain is located in the center of the dished bottom of each loop seal. The flanged brine outlet from the evaporator is at the bottom of the fifth stage.

The distillate loop seal between the distillate collection trough of one stage and the condensers of the following stages also protrude below the bottom of the evaporator.

If the salinity of the distillate reaches .065 EPM per gallon a warning device indicates the high salinity. The salinity cell shutoff valves permit withdrawal and descaling of the salinity cells without securing the unit.

Although each stage condenser produces an equal amount of distillate, the amount flowing from each stage is larger than the preceding, as the distillate cooler. Consequently, the loop seal piping grows progressively larger.

The total distillate production of the five stages is withdrawn from the bottom of stage five and pumped into the shell of the distillate cooler, and on to the storage tanks.

THE DISTILLATE COOLER is a heat exchanger of the shell and tube type, in which the heat of the hot distillate flowing around the tubes is transferred by conduction to the cooler feed water flowing through the tubes.

Distillate flows into the shell space surrounding the tubes through an inlet near the feed water outlet. The distillate is retained in the cooler long enough to efficiently transfer its heat through the tubes by vertically placed baffles, as it flows from top to bottom of the cooler.

Thermometers are mounted on the inlet and outlet piping of the cooler. Another thermometer is mounted on the feed water inlet piping.

As the distillate leaves the cooler it is pumped to storage tanks, providing the salinity does not exceed .065 epm per gallon. (If the salinity exceeds .065 epm per gallon, a solenoid trip valve operated by a salinity indicating cell, dumps the distillate to the bilges or waste tank until the salinity is again back to or below .065 epm per gallon.)

Pet cocks are located on each end of the cooler so as to bleed off any accumulation of air or noncondensable gases.

THE FEEDWATER PREHEATER is a gas or liquid heat exchanger of the shell and tube type, similar in design to the distillate cooler. The preheater is located in the feed water line between the condenser of the first evaporator stage and the salt water heater.

High pressure ship's steam, first used by the air ejectors to evacuate the stage evaporators, is piped into the preheater shell. A series of five baffles, spaced close together in the top steam outlet reduces the velocity of the steam which condenses on the outside of the heat transfer tubes.

Feed water that has already been partially heated in the tubes of the distillate cooler and the five-stage condensers flows through the tubes of the preheater via the front water box in a single pass, acquiring the heat of condensation of the air ejector steam before leaving the preheater at the rear water box outlet.

A salinity cell, set to energize at 0.10 epm operates a shutoff valve in the piping below the condensate outlet to dump high salinity water to bilge or drain tank. A 6-inch loop seal in the condensate line is necessary to ensure that the salinity cell is submerged at all times.

A thermometer is located on the front of the preheater, a pet cock for venting is also located on the water box.

THE SALT WATER HEATER is a gas or liquid heat exchanger designed to raise the feed water temperature prior to its entrance into the flash chamber of the first evaporator stage. The salt water heater is mounted on the operating end of the evaporator and extends the full width of the unit. Feed water enters and leaves the heater from the front water box after making four passes through the heater.

Four thermometers are installed on the heater, two to measure the feed water inlet and outlet temperature; a third, mounted on the heater shell to measure the steam temperature surrounding the tubes; a fourth is mounted on top of the heater shell to measure the temperature of the desuperheating temperature in the steam side.

Low pressure steam in the heater passes through an orifice which provides, within limits, a uniform flow of steam. It then flows past the desuperheater nozzle, which reduces steam temperature in the shell of the heater. Steam pressure is indicated by a pressure gage on the operating panel.

The entering steam is directed along the length of the tubes by impingement baffles, which prevent erosion of the tubes. Steam condenses on the tubes and falls to a condensate well at the bottom of the heater shell. (A drain regulator of the float-type controls the level of the condensate in the well. A salinity cell, set to energize at 0.10 epm controls a shutoff valve located in the ship's piping between the drain pump and regulating valve.) The desuperheater atomizes the heater condensate in the low pressure steam side of the heater.

Since the function of the salt water heater is to provide feedwater to the inlet of the first evaporator stage flash chamber and the amount of heat from the steam is constant, the feed water flow through the heater must be adjusted according to the inlet temperature so the feed water flow is controlled by a valve on the outlet side of the heater.

The air ejector PRECOOLER is a gas or liquid heat exchanger which cools noncondensables and condenses steam drawn from the first three evaporator stages and the salt water heater by a two-stage vacuum-producing air ejector.

The precooler receives its coolant from the feed water pumped into the distilling unit. The flow is through heat transfer tubes, making six passes, entering and leaving at the front end of the coolor.

Steam and noncondensables are drawn into the cooler at the top near the rear of the cooler. Impingment baffles at the inlet and seven vertical baffles through which the transfer tubes run direct the flow of hot gases around the tubes for efficient heat transfer.

Condensate collects on the tubes and drops to the bottom of the shell. A salinity cell operates a shutoff valve in the precooler condensate line to dump to the bilge or drain tank when the salinity is greater than 0.65 epm.

The outlet for noncondensables is mounted on the top of the shell and flanged to the suction chamber of the first ejector of the two-stage air ejector system. The two air ejectors produce a vacuum in the precooler which results in the flow steam and noncondensables from the evaporator.

A thermometer is mounted on the feed water inlet of the cooler.

Cooling water from the air ejector precooler flows into the AFTER-CONDENSER, the fifth of the heat exchangers mounted on the evaporator. The after-condenser completes the condensation of any air ejector steam not condensed in the precooler and cools noncondensable gases before venting them to the atmosphere. It enables the unit to operate without emission of steam from the evaporator.

Cooling water enters and leaves the after-condenser through an inlet pipe in the front, and an outlet pipe in the rear of the condenser.

Air ejector steam and noncondensable gases enter the shell side through an inlet in the front of the unit. Noncondensable gases are vented through a valve on the rear of the unit. A series of vertical baffles direct the steam around the tubes on which it condenses. Condensate is removed through bottom outlets on both ends of the condenser.

A salinity cell set to operate at 0.10 epm controls a shutoff valve below the condenser.

Three high pressure steam-operated vacuum-producing AIR EJECTORS are mounted on the precooler side of the evaporator unit. The ejector system consists of a single-stage (booster) air ejector and a two-stage air ejector arrangement in which the steam outlet from one air ejector is flanged to the suction side of the other.

The single-stage ejector uses ship's steam to draw vapor and noncondensables from evaporator stages four and five. Gases are drawn from the evaporator through a vapor duct in each distillate collection trough so that a minimum of steam is withdrawn. Pipes from stages 4 and 5 lead to a bronze tee flanged to the ejector.

The single-stage ejector steam and entrained gases leave the ejector outlet tubing, flow through a check valve, and reenter the evaporator shell through the top of stage three, from which they are piped into the bottom of the stage three condenser section.

The purpose of this arrangement is to enable the single-stage ejector to produce the high degree of vacuum required in stages four and five. An ejector discharging into a vacuum is able to achieve a higher degree of vacuum than one discharging to atmosphere. A vacuum of 28 inches of mercury is required in stage five.

The two-stage ejector draws noncondensables from the salt water heater and the first three evaporator stages. Since the noncondensables from stages four and five are directed back into stage three, the two-stage ejector, therefore, actually handles all noncondensables within the unit.

The suction chamber of the second ejector is flanged to the noncondensables outlet of the precooler through which the gases pass before entrainment in the air ejector steam. The two-stage ejectors use ship's steam and produce a vacuum in the precooler slightly greater than in the first evaporator stage.

Orifice plates of varying size are flanged into the piping from the evaporator stages and salt-water heater leading to the air ejectors. These plates prevent the air ejectors from withdrawing an undue amount of steam from the evaporator along with the noncondensables.

The discharge of the second ejector is flanged to the suction chamber of the third ejector. The discharge of the third ejector is flanged to piping, containing a check valve, which runs diagonally across the top of the evaporator shell to the air ejector steam inlet of the preheater shell near the front water box.

The pressure of ship's steam piped to the ejectors is indicated on the independently mounted pressure gage panel. Line pressure to the air ejectors must be maintained at or above 135 psig, as a lower pressure will cause unstable operation of the ejector and will affect the vacuum in the evaporator.

A DUPLEX STRAINER, located in the ship's feed water inlet piping, removes solid matter from sea water by filtering through one of two perforated and screened bronze baskets. Basket wells are located in the body or housing of the strainer on either side of the centrally located flanged inlet and outlet.

A lever handle between the wells directs the feedwater into the left-or right-hand well. When one basket becomes clogged, flow is switched to the other and the clogged basket should be removed and cleaned.

An inlet and outlet angle-type RELIEF VALVE is flanged into the feed water inlet between the feed water pump and the air ejector precooler. The valve is set to open at 75 psig to prevent pressure buildup from an obstruction in the feed water lines or accidental operation of the feed water pump with the feed water control valve closed.

Two FLOWRATORS are mounted on the unit to measure the amount of feed water and cooling water pumped into the system. Since the amount of fluid to be measured in both cooling and feed water lines is large, the flowrators are mounted in bypass piping arrangements, measuring a small portion of the actual main stream flow but providing a reading on the graduated scale of the cylinder for the entire flow. Main stream and range orifices are provided for each flowrator.

The flowrators serves as manometers. The pressure drop across the manometer is equal to the pressure drop created by the constriction of the main stream orifice. The range orifice at the inlet of the flowrator constricts the bypass flow so that a maximum main stream flow will register a maximum reading on the flowrator scale.

It is, therefore, essential that main stream and range orifices be in good condition and of proper bore diameter, if correct readings are to be obtained on the flowrators. The size of the orifice bore should be checked regularly. When cleaning orifice plates and checking bore diameter (stamped on the plates), be careful not to damage the metering edge (the upstream edge). It must be square and sharp, free of either burrs or rounding so that the corner does not reflect light when viewed with magnification. Piping should also be inspected to see that scale deposits have not decreased the inside diameter.

MAINTENANCE OF FLASH TYPE UNITS

Many maintenance procedures for a flash type distilling plant are similar to the maintenance procedures required for a submerged tube plant. Both types of plants are subject to air leakage, salt water leakage, and malfunctioning of pumps and other auxiliary equipment. Some of the more important maintenance problems will be discussed in the following paragraphs.

Air Leakage

Since all parts of the distilling plant are designed to operate under a vacuum except the circulating, feed, and fresh water lines, extreme care must be taken to prevent leakage of air which might seriously interfere with the proper operation of the plant.

The brine overboard and distillate pumps take their suction from points of relatively high vacuum. Air leakage in the piping to these pumps is particularly objectionable and must be eliminated. A small amount of air entering these lines, even though it is insufficient to affect the distilling plant vacuum, may cause the pump to lose suction. Leaks in the lines to the pump suction gages must not be overlooked.

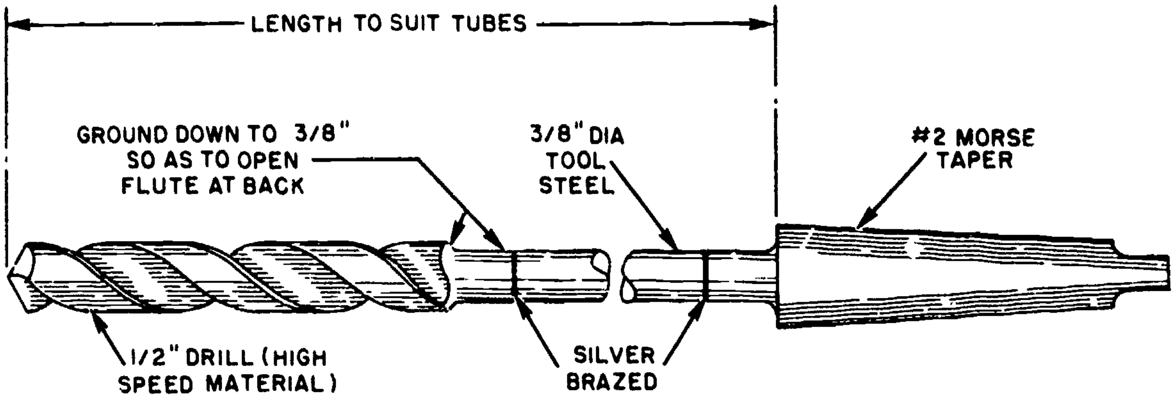
An 8 to 10 psig, low pressure hydrostatic test should be applied to the entire system in accordance with the Planned Maintenance System, and at any other time when there is an indication that air leakage may exist. The salt water circulating pump can be used to apply the pressure.

Pumps

Proper operation of all pumps is essential for the successful operation of the distilling plant. The effect of air leakage into the suction line of the pumps has been discussed in the preceding paragraph. Proper operation of the water sealed gland lines and proper maintenance of the glands themselves are necessary for dependable operation of the pumps. General information on operation and maintenance of pumps may be found in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D, and in this training manual; however, for details of any specific pump, consult the manufacturer's technical manual.

Salt Water Leakage

Salt water to distillate or salt water to condensate leaks at any of the various tube bundles will be immediately indicated by an alarm bell and a red light which shows at which cell a conductivity increase has occurred. The



96.31

Figure 8-1.–Tool for removing scale inside tubes.

cells are located downstream from each tube bundle. Tube leaks usually result from damaged or corroded tubes or from improper expansion of tubes into tube sheets.

Faulty tubes may be sealed with plastic tube plugs or may be removed and replaced in accordance with standard Navy procedures, as given in chapter 9581 of NAVSHIPS Technical Manual.

Cleaning Heat Exchangers

The tubes of the distillate cooler, air ejector condenser, and the stage condensers operate with comparatively cool salt water inside them and will seldom require cleaning. The sea water in the salt water heater is at a higher temperature and these tubes will occasionally require cleaning to remove the hard scale on the inside of the tubes. A special tool is furnished for this purpose; this cleaning tool is shown in figure 8-1.

The procedure for cleaning salt water heaters is as follows: Remove the waterheads. Insert the special cleaning tool in the tube and drive it with a 250 to 300 rpm motor. The motor should be of the reversible type. Feed a light stream of water into the opposite end of the tube to wash the scale from the cutting tool and out of the tube. A light stream of compressed air may be substituted in place of the water. Care should be taken not to drive the tool too fast and to be certain that the tool is straight when inserted into the tube.

An 8 to 10 psig hydrostatic test should be performed on the shell of the salt water heater before replacing the heads. If a greater test pressure is used, the relief valve will have to be plugged or removed.

Cleaning Feed Boxes

If feed flow is below normal and the distiller feed pump discharge is normal, the first-stage flash orifices may be plugged. Fouling of the second-stage orifices may be evidenced by water backing up into the first stage; however, the second-stage orifices are larger and will not be as readily plugged. Water backing into the first stage may also be caused by insufficient pressure difference between the stages.

Since the temperatures that exist in the feed boxes are well below the range in which salt water scale forms, the only plugging or fouling expected at the orifices would come from the introduction of foreign matter into the system. Should the orifices in either stage become plugged, it will be necessary to remove the access plate at the front of the unit, remove the perforated plates from the feed box and remove the obstructing material from the orifices. The feed boxes are constructed so that the front can be readily removed for access to the orifices.

CHAPTER 9

REFRIGERATION AND AIR CONDITIONING

As a MM 3 & 2, you learned the principles of refrigeration and air conditioning, and the components and accessories that make up the system. You learned how to start, operate, and secure refrigeration plants. In addition, you have performed routine maintenance jobs such as checking for noncondensable gases, pumping down the system, using the halide torch to test for leaks, and changing the lubricating oil in refrigeration compressors. As you advance in rate, you will be expected to have a greater knowledge of the construction and operating principles of refrigerating equipment. You will be required to perform more complicated maintenance jobs, to make repairs as required and to determine the causes of inefficient plant operation and accomplish the necessary corrective procedures.

This chapter provides information that supplements related information in other training manuals applicable to your rating and that is related to the qualifications for advancement. Information is included on the construction and maintenance of refrigeration and air conditioning equipment, and the detection and correction of operating difficulties.

The manufacturer's technical manual should be referred to for details of the plant on your ship.

COMPRESSORS

Many different types and sizes of compressors are used in refrigeration and air conditioning systems. They vary from the small hermetic units used in drinking fountains and refrigerators, to the large centrifugal units used for air conditioning.

One of the most commonly encountered compressors on today's modern ships in a high speed unit with a variable capacity. This compressor is of the multicylinder, reciprocating design, with an automatic device built into the compressor to control the compressor's output. The automatic capacity control provides for continuous compressor operation under normal load conditions.

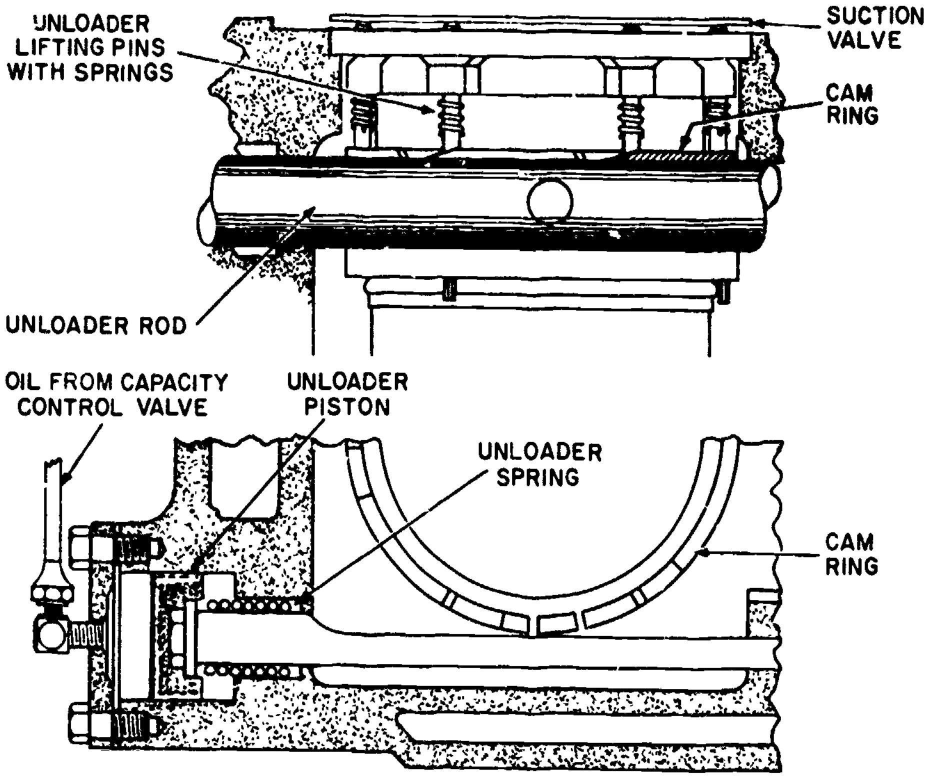
CAPACITY CONTROL

Controlling the capacity of the compressor is accomplished by unloading and loading of the cylinders. This is a very desirable design feature of the unit, because if the compressor is to be started under a load, or all cylinders working, there is a much greater amount of torque required and it is necessary to have a much larger drive motor. Also, if the compressor is running at a constant capacity or output, it will reach the low temperature or pressure limits or be constantly starting and stopping, thereby putting excessive work on the unit.

Unloading of the cylinders in the compressor is accomplished by lifting the suction valves off their seats and holding them open. This method of capacity control unloads the cylinders completely and allows the compressor to work at as much as 25 percent of its rated capacity.

Unloader Mechanism

When the compressor is not in operation, the unloader mechanism which is operated by oil pressure from the capacity control valve, is in the unloaded position as shown in figure 9-1. Referring to figure 9-1, used as an examr' for



121.34

Figure 9-1.—Unloader mechanism in unloaded position.

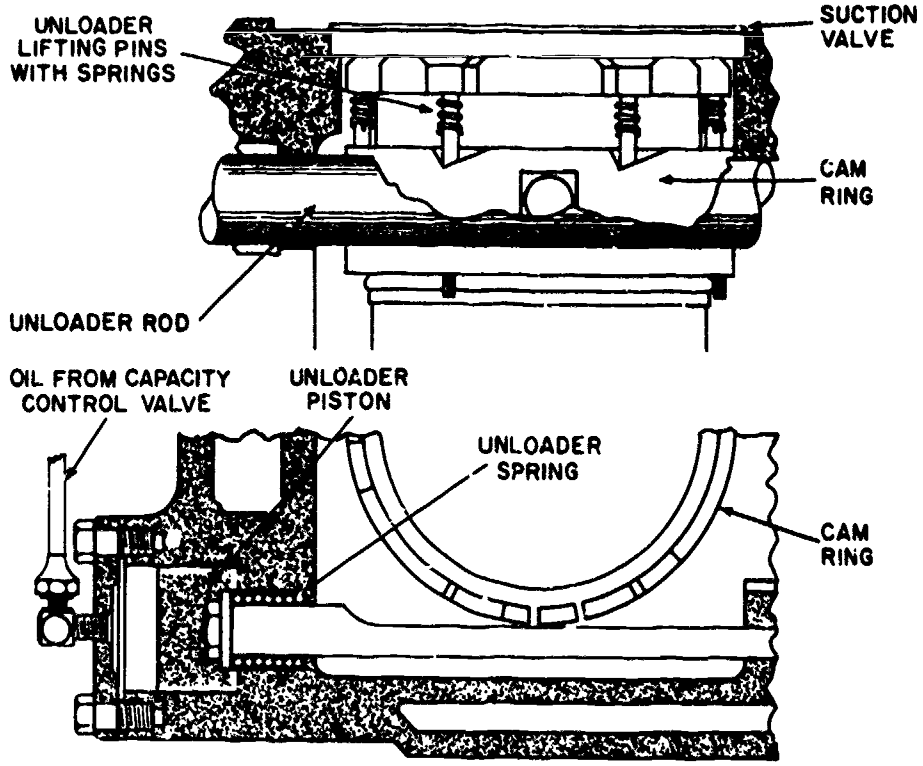
one type of system, the unloader spring pushes against the unloader piston. This action moves the unloader rod to the left, thereby rotating the cam rings. As the cam rings are rotated, the lifting pins are forced upward raising the suction valve off its seat. The suction valve is held in this position until the compressor is started and oil pressure of approximately 30 psi is reached. At this time, the oil pressure from the capacity control valve pushes the unloader piston back to the right against the unloader spring. The motion transmitted through the push rod rotates the cam ring, thus lowering the lifting pins and allowing the suction valve to close or operate normally and the cylinder to become loaded (fig. 9-2). On most compressors the unloader is connected to the cylinders in pairs.

Capacity Control Valve

The capacity control valve (fig. 9-3) is located ...e compressor crankcase cover. The valve is actuated by oil pressure from the main oil pump and its function is to admit or relieve oil to or from the individual unloader power elements, depending on suction or crankcase pressure. Referring to figure 9-3, when the compressor is at rest the two cylinders equipped with the unloader element will be unloaded and remain unloaded until the compessor is stated and the oil pressure reaches normal operating pressure.

The high pressure oil from the pump enters chamber A of the capacity control valve and passes through an orifice in the top of the piston to chamber B, forcing the piston to the end of its stroke against spring A. When the piston of the valve is forced against spring A, the circular grooves which form chamber A are put in communication with the unloader connections. This admits high pressure oil to the unloader cylinder, actuating the unloader mechanism.

To control oil pressure from the capacity control valve, a capacity control regulating valve is installed. It is connected to the crankcase and



121.35

Figure 9-2.—Unloader mechanism in loaded position.

has an oil connecting line to chamber B of the capacity control valve. As the crankcase or suction pressure pulls down slightly below the setting of the regulating valve, the regulator opens and relieves oil pressure from chamber B of the capacity control valve. (See fig. 9-3.) This permits spring A to push the capacity control piston one step toward chamber B, uncovering the unloader connection nearest the end of the capacity control valve. This relieves oil pressure from the power element and allows the power element spring to rotate the cam rings and unload the cylinder.

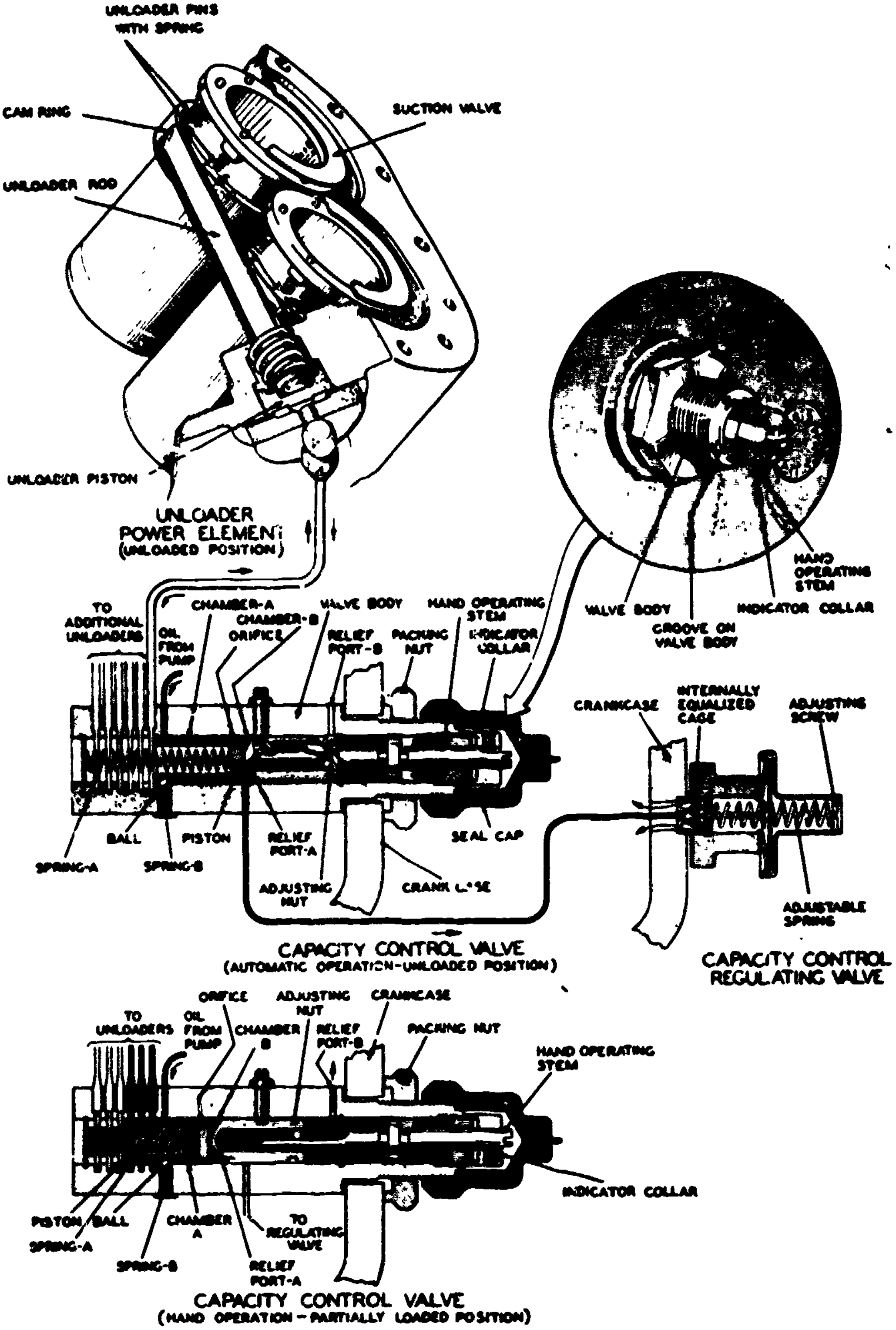
If the suction pressure continues to drop, the regulator will relieve more oil pressure and more cylinders will become unloaded. If the heat load increases, the suction pressure will increase causing the regulating valve to close and more cylinders to become loaded.

COMPRESSOR MAINTENANCE

As an MM1 or MMC, maintaining the refrigeration and air conditioning plants may be one of your responsibilities. In order for you to perform the required maintenance you must understand the proper maintenance procedures. In most instances, personnel who are assigned to maintain refrigeration plants are graduates of the Navy's Air Conditioning and Refrigeration School. While this school teaches most operating and maintenance procedures, the manufacturer's technical manuals should be referred to for the details of the plants on your ship.

Testing Suction and Discharge Valves

Faulty compressor valves may be indicated either by a gradual or a sudden decrease in the



121.36

Figure 9-3.—Capacity control system.

normal compressor capacity. Either the compressor will fail to pump at all, or else the suction pressure cannot be pumped down to the designed value, and the compressor will run for abnormally long intervals or even continuously. A rapid build up of suction (crankcase) pressure during an off cycle, causing the compressor to start after a very short off period will indicate leaking discharge valves.

If the refrigeration plant is not operating satisfactorily, it will be best to first shift the compressors and then check the operation of the plant. If the operation of the plant is satisfactory when the compressors have been shifted, the trouble is in the compressor, and not in the system.

The compressor discharge valves may be tested by pumping down the compressor to 2 psig, and then stopping the compressor and quickly closing the suction and discharge line valves. If the discharge pressure drops at a rate in excess of 3 pounds in a minute and the crankcase suction pressure rises, there is evidence of compressor discharge valve leakage. If it is necessary to remove the discharge valves with the compressor pumped down, open the connection to the discharge pressure gage in order to release discharge pressure on the head. Then remove the compressor top head and discharge valve plate, being careful not to damage the gaskets.

If the discharge valves are defective, the entire discharge valve assembly should be replaced. Any attempt to repair them would probably involve relapping, and would require highly specialized equipment. Except in an emergency, such repair should never be undertaken aboard ship.

The compressor internal suction valves may be checked for leakage as follows:

1. Start the compressor by using the manual control switch on the motor controller.

2. Close the suction line stop valve gradually, to prevent violent foaming of the compressor crankcase lubricating oil charge.

3. With this stop valve closed, pump a vacuum of approximately 20 inches Hg. If this vacuum can be readily obtained, the compressor suction valves are satisfactory.

Do not expect the vacuum to be maintained after the compressor stops, because the Refrigerant-12 is being released from the crankcase oil. Do not attempt to check compressor suction valve efficiency of new units until after the compressor has been in operation for a minimum of 3 days. It may be necessary for the valves to wear in.

However, if any of the compressor suction valves are defective, the compressor should be pumped down, opened, and the valves inspected. Defective valve(s) or pistons should be replaced with spare assemblies.

Crankshaft Seal Repairs

On reciprocating compressors, the crankshaft extends through the compressor housing to provide a mount for the pulley wheel or flexible coupling. At this point, the shaft must be sealed to prevent leakage of lubricating oil and refrigerant. There are several types of crankshaft seals, depending on the manufacturer. The crankshaft seal is bathed in lubricating oil at a pressure equal to the suction pressure of the refrigerant. The first indication of crankshaft seal failure is excessive oil leaking at the shaft.

When the seal requires replacement, or signs of abnormal wear or damage to the running surfaces are present, a definite reason for the abnormal conditions exists and an inspection should be made. It is very important to locate and correct the trouble or the failure will reoccur.

Seal failure is very often the result of faulty lubrication, usually due to the condition of the crankcase oil. A dirty or broken oil seal is generally caused by one or both of the following conditions:

1. Dirt or foreign material in the system or system piping. Dirt frequently enters the system at the time of installation. After a period of operation, foreign material will always accumulate in the compressor crankcase, tending to concentrate in the oil chamber surrounding the shaft seal. When the oil contains grit, it is only a matter of time until the highly finished running faces become damaged, causing failure of the shaft seal.

2. Moisture is frequently the cause of an acid condition of the lubricating oil. Oil in this condition will not provide satisfactory lubrication and will promote failure of the compressor parts. If the presence of moisture is suspected, a refrigerant dehydrator should be used when the compressor is put into operation. At any time foreign material is found in the lubricating oil, the entire system (piping, valves, and strainers) should be cleaned thoroughly.

REMOVING SHAFT SEAL.–In the event a shaft seal must be renewed, proceed as follows:

If the seal is broken to the extent that it permits excessive oil leakage, do not attempt to pump the refrigerant out of the compressor, air (containing moisture) will be drawn into the system through the damaged seal. Moisture entering the refrigerant system may cause expansion valves to freeze causing acid formation and possibly other problems. If oil is leaking excessively, close the compressor suction and discharge valves and relieve the pressure to the atmosphere by loosening a connection on the compressor discharge gage line.

Next drain the oil from the compressor crankcase. Since the oil contains refrigerant, it will foam while being drained. The oil drain valve or plug should be left open while you are working on the seal, so that refrigerant escaping from the oil remaining in the crankcase will not build up a pressure–and unexpectedly blow out the seal while it is being removed.

Remove the compressor flywheel (or coupling) and carefully remove the shaft seal assembly. If the assembly cannot be readily removed, build up a slight pressure in the compressor crankcase by slightly opening the compressor suction valve, taking the necessary precautions to support the seal to prevent it from being blown from the compressor and damaged.

INSTALLING SHAFT SEAL.–When the replacement is made, the entire seal assembly should be cleaned and replaced in accordance with the manufacturer's instructions.

Wipe the shaft clean with a linen or silk cloth; do not use a dirty or lint-bearing cloth. Unwrap the seal, being careful not to touch the bearing faces with the hands. Rinse the seal in an approved solvent and allow to air-dry. (Do not wipe the seal dry.) Dip the seal in clean refrigerant oil. Insert the assembly in accordance with the instructions found in the manufacturer's technical manual and bolt the seal cover in place, tightening the bolts evenly. Replace the flywheel and belts or coupling, check and correct motor and compressor shaft alignment, and test the unit for leaks by opening the suction and discharge valves and using a halide leak detector.

Evacuating the Compressor

Whenever repairs to a compressor are of such a nature that any appreciable amount of air enters the unit, the compressor should be evacuated, after assembly is completed and before it is ready for operation. The proper procedure is as follows:

1. Disconnect a connection in the compressor discharge gage line, between the discharge line stop valve and the compressor.

2. Start the compressor and let it run until the greatest possible vacuum is obtained.

3. Stop the compressor and immediately open the suction stop valve slightly in order to blow refrigerant through the compressor valves and purge the air above the discharge valves through the open gage line.

4. Close the discharge gage line and open the discharge line stop valve.

5. Remove all oil from the exterior of the compressor, and test the compressor joints for leakage using the halide leak detector.

Cleaning Suction Strainers

When putting a new unit into operation, the suction strainers should be cleaned after a few hours of operation. Refrigerants have a solvent action and will loosen any foreign matter in the system. This foreign matter will eventually reach the suction strainers. After a few days of operation, the strainers will need another cleaning. They should be inspected frequently during the first few weeks of plant operation, and then cleaned as found necessary.

The suction strainers are located in the compressor housing or in the suction piping. The procedure for cleaning the strainers is as follows:

1. Pump down the compressor.
2. Remove the strainer and inspect it for foreign matter.
3. Clean the strainer screen by dipping it in an approved solvent and then allow it to dry.
4. Replace the strainer and evacuate the air from the compressor.
5. Test the housing for leaks by wiping up all oil and then using a halide leak detector.

Maintenance Precautions

If a compressor cannot be pumped down and is damaged to the extent that it has to be opened for repairs, it is necessary to first close the suction and discharge valves and then allow all refrigerant in the compressor to vent to the atmosphere, through a gage line.

When it becomes necessary to remove, replace, or repair internal parts of the compressor, the following precautions should be observed:

1. Carefully disassemble and remove parts, noting the correct relative position so that errors will not be made when reassembling.
2. Inspect all those parts that become accessible due to the removal of other parts requiring repair or replacement.
3. Make certain that all parts and surfaces are free of dirt and moisture.
4. Apply clean compressor oil freely to all bearing and rubbing surfaces of parts being replaced or reinstalled.
5. If the compressor is not equipped with an oil pump, make certain that the oil dipper on the lower connecting rod is in correct position for dipping oil when the unit is in operation.
6. Position the ends of the piston rings so that alternate joints come on the opposite side of the piston.
7. Care should be taken not to score gasket surfaces.
8. Renew all gaskets.
9. Clean the crankcase and renew the oil.

CONDENSERS

The compressor discharge line terminates at the refrigerant condenser. In shipboard R-12 installations, these condensers are usually of the multipass shell-and-tube type, with water circulating through the tubes. The tubes are expanded into grooved holes in the tube sheet so as to make an absolutely tight joint between the shell and the circulating water. Refrigerant vapor is admitted to the shell, and condenses on the outer surfaces of the tubes.

Any air or noncondensable gases which may accidentally enter the refrigeration system will be drawn through the piping and eventually discharged into the condenser with the R-12 gas. The air or noncondensable gases accumulated in the condenser are lighter than the refrigerant gas and will rise to the top of the condenser when the plant is shut down. A purge valve, for purging the refrigeration system (when necessary), is installed at the top of the condenser, or at a high point in the compressor discharge line.

CLEANING CONDENSER TUBES

In order to clean the condenser tubes properly, it is necessary first to drain the cooling water from the condenser and then disconnect the water connections and remove the condenser heads. When the condenser heads are removed, be careful not to damage the gaskets between the tube sheet and the water side of the condenser heads. Tubes should be inspected as often as practicable and be cleaned as necessary, using an approved method. Rubber plugs and an air or water lance should be employed when necessary to remove foreign deposits. It is essential that the tube surfaces be kept clear of particles of foreign matter; however, care must be taken not to destroy the thin protective coating on the inner surfaces of the tubes. If the tubes become badly corroded, they should be replaced in order to avoid the possibility of losing the R-12 charge and admitting salt water to the R-12 system.

CLEANING AIR-COOLED CONDENSERS

Although the large plants are equipped with water-cooled condensers, auxiliary units are commonly provided with air-cooled condensers. The use of air cooled condensers eliminates the necessity for circulating water pumps and piping.

The exterior surface of the tubes and fins on an air-cooled condenser should be kept free of dirt or any matter that might obstruct heat flow and air circulation. The finned surface should be brushed clean with a stiff bristle brush as often as necessary. The use of low pressure air will prove very useful in removing dirt from condensers that are in hard to reach places. When installations are exposed to salt spray, and rain through open doors or hatches, care should be taken to minimize corrosion of the exterior surfaces.

TESTING FOR LEAKS

To prevent serious loss of refrigerant through leaky condenser tubes, the condenser should be tested for leakage every week. A condenser that has not been in use for the preceding 12 hours should be tested.

To test for leaky condenser tubes, drain the water side of the condenser and insert the exploring tube of the leak detector through one of the drain plug openings. If this test indicates that R-12 gas is present, the exact location of the leak may be detected as follows:

1. Remove the condenser heads.
2. Clean and dry tube sheets and ends of the tubes.
3. Check both ends of each tube with a leak detector. Mark any tubes which show an indication of leakage. If it cannot be determined if the tube is leaking internally or around the tube sheet joint, plug the suspected tube and again check around the tube sheet joint. Mark adjacent tube, if necessary, to isolate the suspected area.
4. To locate or isolate very small leaks in the condenser tubes, hold the exploring tube at one end of the condenser tube for about 10 seconds to draw fresh air through the tube. Then drive a plug in each end of the tube. Repeat this procedure with all the tubes in the condenser. Allow the condenser tubes to remain plugged for 4 to 6 hours; then, remove the plugs one at a time and check each tube for leakage. If a leaky tube is detected replace the plug immediately to reduce the amount of refrigerant escaping. Make appropriate repairs or mark and plug all leaky tubes for later repairs.

RETUBING CONDENSERS

The general procedure for retubing condensers is outlined in chapter 9590 of NAVSHIPS Technical Manual. The procedure given in the applicable manufacturer's technical manual should be followed when a condenser of a specific type is being retubed.

THERMOSTATIC EXPANSION VALVES

When the thermostatic expansion valve is operating properly, the temperature at the outlet side of the valve is much lower than that at the inlet side. If this temperature difference does not exist when the system is in operation, the valve seat is probably dirty and clogged with foreign matter.

Once a valve is properly adjusted, further adjustment should not be necessary. The major trouble encountered can usually be traced to moisture or dirt collecting at the valve seat and orifice.

TESTING AND ADJUSTMENT

By means of a gear and screw arrangement, the thermostatic expansion valves used in most shipboard systems can be adjusted to maintain a superheat ranging approximately from 4° to 12°F at the cooling coil outlet. The proper superheat adjustment varies with the design and service operating conditions of the valve, and the design of the particular plant. Increased spring pressure increases the degree of superheat at the coil outlet and decreased pressure has the opposite effect. Some thermostatic expansion valves have a fixed (non-adjustable) superheat. These valves are used in equipment or systems where the piping configuration and evaporating conditions are constant, primarily in self contained equipment.

If expansion valves are adjusted to give a high superheat at the coil outlet, or if the valve is stuck shut, the amount of refrigerant admitted to the cooling coil will be reduced. With an insufficient amount of refrigerant, the coil will be "starved" and will operate at a reduced capacity. Also, the velocity of the refrigerant through the coil may not be adequate to carry oil through the coil, thus robbing the compressor crankcase, and providing a condition whereby slugs of lubricating oil may be drawn back to the compressor. If the expansion valve is adjusted for too low a degree of superheat, or if the valve is stuck open, liquid refrigerant may flood from the cooling coils back to the compressor. Should the liquid refrigerant collect at a low point in the suction line or coil, and be drawn back to the compressor intermittently in slugs, there is danger of injury to the moving parts of the compressor.

In general, the expansion valves for air conditioning and water cooling plants (high temperature installations) normally are adjusted for higher superheat than the expansion valves for cold storage refrigeration and ship's service store equipment (low temperature installations).

If it is impossible to adjust expansion valves to the desired settings, or if it is suspected that the expansion valve assembly is defective and requires replacement, appropriate tests must be made. (First be sure that the liquid strainers are clean, that the solenoid valves are operative, and that the system is sufficiently charged with refrigerant.)

The major equipment required for expansion valve tests is as follows:

1. A service drum of R-12, or a supply of clean dry air at 70 to 100 psig. The service drum is used to supply gas under pressure. The gas used does not have to be the same as that employed in the thermal element of the valve being tested.

2. A high pressure and a low pressure gage. The low pressure gage should be accurate and in good condition so that the pointer does not have any appreciable lost motion. The high pressure gage, while not absolutely necessary, will be useful in showing the pressure on the inlet side of the valve. Refrigeration plants are provided with suitable replacement and test pressure gages.

The procedure for testing is as following:

1. Connect the valve inlet to the gas supply with the high pressure gage attached so as to indicate the gas pressure to the valve, and with the low pressure gage loosely connected to the expansion valve outlet. The low pressure gage is connected up loosely so as to provide a small amount of leakage through the connection.

2. Insert the expansion valve thermal element in a bath of crushed ice. Do not attempt to perform this test with a container full of water in which a small amount of crushed ice is floating.

3. Open the valve on the service drum or in the air supply line. Make certain that the gas supply is sufficient to build up the pressure to at least 70 psi on the high pressure gage connected in the line to the valve inlet.

4. The expansion valve can now be adjusted. If it is desired to adjust for 10°F superheat, the pressure on the outlet gage should be 22.5 psig. This is equivalent to an R-12 evaporating temperature of 22°F, and since the ice maintains the bulb at 32°F, the valve adjustment is for 10°F superheat (difference between 32 and 22). For a 5°F superheat adjustment, the valve should be adjusted to give a pressure of approximately 26.1 psig. There must be a small amount of leakage through the low pressure gage connection while this adjustment is being made.

5. To determine if the valve operates smoothly, tap the valve body lightly with a small weight. The low pressure gage needle should not jump more than 1 psi.

6. Now tighten the low pressure gage connection so as to stop the leakage at the joint, and determine if the expansion valve seats tightly. With the valve in good condition, the pressure will increase a few pounds and then either stop or build up very slowly. With a leaking valve, the pressure will build up rapidly until it equals the inlet pressure. With externally equalized valves, the equalizer line must be connected to the piping from the valve outlet to the test gage, to obtain an accurate superheat setting.

7. Again loosen the gage so as to permit leakage at the gage connection; remove the thermal element, or control bulb, from the crushed ice, and warm it with the hand or place it in water that is at room temperature. When

this is done, the pressure should increase rapidly, showing that the power element has not lost its charge. If there is no increase in pressure, the power element is dead.

8. With high pressure showing on both gages as outlined above, the valve can be tested to determine if the body joints or the bellows leak. This can be done by using a halide leak detector. When performing this test, it is important that the body of the valve have a fairly high pressure applied to it. In addition, the gages and other fittings should be made up tightly at the joints so as to eliminate leakage at these points.

REPLACEMENT OF VALVES

If it is evident that the expansion valve is defective, it must be replaced. Most valves used on naval ships have replaceable assemblies and it is possible to replace a faulty power element or other part of the valve without having to replace the entire assembly. When replacement of an expansion valve is necessary, it is important to replace the unit with a valve of the same capacity and type.

ADDITIONAL SYSTEM MAINTENANCE

In addition to the maintenance of the components described above, there are other parts of the system that will need periodic maintenance to keep the plant operating properly.

Vibration may cause leakage in the piping system allowing air and moisture to be drawn in or a loss of the refrigerant charge. If this happens, the plant operation will become erratic and inefficient, and the cause of trouble must be corrected.

CHARGING THE SYSTEM

Information concerning the charging of refrigeration systems may be found in chapter 9590 of NAVSHIPS Technical Manual. The amount of refrigerant charge must be sufficient to maintain a liquid seal between the condensing and evaporating sides of the system. When the compressor stops, under normal operating conditions, the receiver of a properly charged system is about 85 percent full of refrigerant. The proper charge for a specific system or unit can be found in the manufacturer's technical manual or on the ship's blueprints.

A refrigeration system should not be charged if there are leaks or if there is reason to believe that there is a leak in the system. The leaks must be found and corrected. Immediately following–or during–the process of charging, the system should be carefully checked for leaks.

A refrigeration system must have an adequate charge of refrigerant at all times; otherwise its efficiency and capacity will be impaired.

PURGING THE SYSTEM

To determine if there are noncondensable gases in the system, operate the system for 30 minutes. Stop the compressor for 10 to 15 minutes, leaving all valves in their normal position. Observe the pressure and temperature as indicated on the high pressure gage. Read the thermometer in the liquid line, or the temperature of the cooling water discharge from the condenser, and compare it with the temperature conversion figures shown on the discharge pressure gage. If the temperature of the liquid leaving the receiver is more than 5°F lower than the temperature corresponding to the discharge pressure, the system should be purged. Pump the system down and secure the compressor; then open the purge valve on the condenser. Purge very slowly, at intervals, until the air is expelled from the system and the temperature difference drops below 5°F.

CLEANING LIQUID LINE STRAINERS

Where a liquid line strainer is installed, it should be cleaned at the same intervals as the suction strainer. If a liquid line strainer becomes clogged to the extent that it needs cleaning, a loss of refrigeration effect will take place The tubing on the outlet side of the strainer will be much colder than the tubing on the inlet side.

To clean the liquid line strainer, secure the receiver outlet valve and wait a few minutes to allow any liquid in the strainer to flow to the cooling coils. Then close the strainer outlet valve and very carefully loosen the cap which is bolted to the strainer body. (Use goggles to protect the eyes.) When all the pressure is bled out of the strainer, remove the cap and lift out the strainer screen. Clean the strainer screen, using an approved solvent and a small brush. Reassemble the spring and screen in the strainer body, then replace the strainer cap loosely. Purge the air out of the strainer, by blowing refrigerant through it; then tighten the cap. After the assembly is complete, test the unit for leaks.

CLEANING OIL FILTERS AND STRAINERS

Compressors arranged for forced feed lubrication are provided with lubricating oil strainers in the suction line of the lube oil pump and an oil filter may be installed in the pump discharge line. A gradual decrease in lubricating oil pressure indicates that these units need cleaning. This cleaning may be accomplished in much the same manner as described for cleaning suction strainers.

When cleaning is necessary, the lubricating oil in the crankcase should be drained from the compressor and a new charge of oil, equal to the amount drained, should be added before restarting the unit. When the compressor is put back into operation, the lube oil pressure should be adjusted to the proper setting by adjustment of the oil pressure regulator.

MAINTAINING COOLING COILS

Cooling coils should be inspected regularly and cleaned as required. The cooling coils should be defrosted as often as necessary to maintain the effectiveness of the cooling surface. Excessive build-up of frost on the cooling coils will result in reduced capacity of the plant, low compressor suction pressure, and a tendency for the compressor to short-cycle. The maximum time interval between defrosting depends on many factors, such as refrigerant evaporating temperature, condition of door gaskets, moisture content of supplies placed in boxes, frequency of opening of doors and atmospheric humidity.

It is good to always defrost the cooling coils before the frost thickness reaches three-sixteenths of an inch. When defrosting, ensure that the frost is not scraped or broken off as this ... cause damage to the coils.

EVACUATING AND DEHYDRATING THE SYSTEM

Where moisture accumulation must be corrected, the system should first be cleared of refrigerant and air. The time required for these processes will depend upon the size of the system and the amount of moisture present. It is good engineering practice to circulate heated air through a large dehydrator and system for several hours, or as long as the dehydrator drying agent remains effective, before proceeding with the evacuation process. If possible, the dehydrated air should be heated to about 240°F.

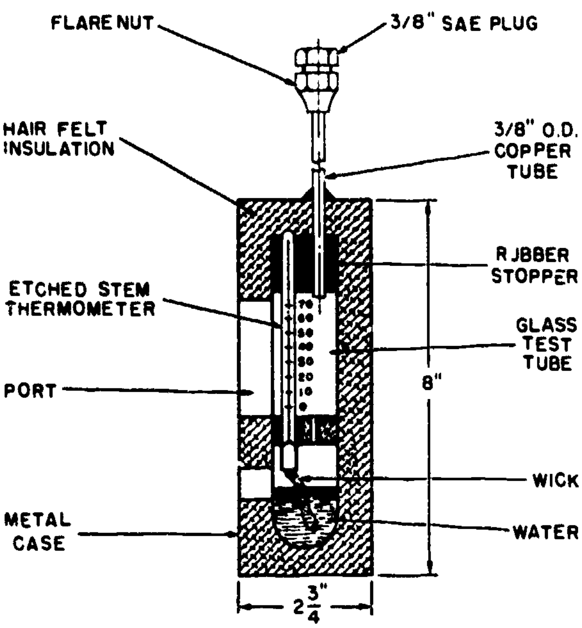
Large dehydrators, suitable for preliminary dehydration of refrigeration systems, are usually available at naval shipyards, and aboard tenders and repair ships.

After the preliminary dehydration, remaining moisture is evacuated by means of a two-stage high-efficiency vacuum pump having a vacuum indicator. (These vacuum pumps are available aboard tenders and repair ships.)

The vacuum indicator shown in figure 9-4 consists o an insulated test tube containing a wet bulb thermometer with its wick immersed in distilled water. The indicator is connected in the vacuum pump suction line. The suction line from the vacuum pump is connected to the refrigeration system. The refrigerant circuit should be closed to the atmosphere and the charging connection opened to the vacuum pump.

A two-stage pump is started for operation in PARALLEL so that maximum displacement may be obtained during the initial pump-down stages. When the indicator shows a temperature of about 55°F (0.43 inch Hg, absolute), the pumps are placed in SERIES operation (wherein the discharge from the first step enters the suction of the second step pump). The dehydration process will be reflected in the temperature drop of the vacuum indicator as shown in figure 9-5. Readings will intially reflect ambient temperatures, then show rapidly falling temperatures until the water in the system starts to boil.

When most of the evaporated moisture has been evacuated from the system, the indicator will show a decrease in temperature. When the temperature reaches 35° (0.2 inch Hg, absolute),



CONVERSION TEMPERATURE °F TO ABSOLUTE PRESSURE INCHES MERCURY

TEMPERATURE °F	ABSOLUTE PRESSURE INCHES MERCURY
60	0 521
55	0 436
50	0 362
45	0 300
40	0 248
35	[illegible]
32	0 181

96.32

Figure 9-4.—Dehydrator vacuum indicator.

dry air should be admitted through a chemical dehydrator into the system at a point farthest from the pump. Continue operating the pump; the dry air will mix with and dilute any remaining moisture. Secure the opening which feeds the dry air to the system. Continue evacuating the system until the indicator again shows a temperature of 35°F. At this time, the dehydration process is complete. Close the valves and disconnect the vacuum pump.

Sometimes it will be impossible to obtain a temperature as low as 35°F in the vacuum indicator; the probable reasons for such a failure, and the corrective procedures to take, are as follows:

1. Presence of excess moisture in the system. The dehydration procedure should be conducted for longer periods.

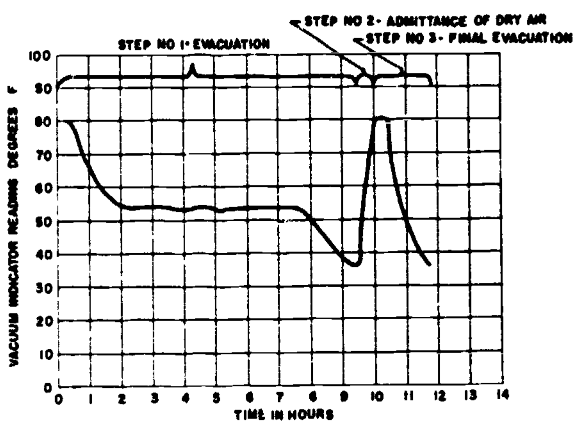
2. Presence of absorbed refrigerant in the lubricating oil contained in the compress crankcase. Remove the lubricating oil from the crankcase before proceeding with the dehydration process.

3. Leakage of air into the system. The leak must be found and stopped. It will be necessary to repeat the procedure required for detecting leaks in the system.

4. Inefficient vacuum pump or defective vacuum indicator. The defective unit(s) should be repaired or replaced.

Immediately after each period of use, or after the system has been opened for repairs, the drying agent in the dehydrator should be replaced. If a replacement cartridge is not available, the drying agent can be reactivated and used until a replacement is available.

Reactivation is accomplished by removing the drying agent and heating it, for 12 hours, at a temperature of 300°F to bake out the moisture. The drying agent may be placed in an oven, or a stream of hot air may be circulated through the cartridge. These methods are satisfactory for reactivating commonly used dehydrating agents such as activated alumina and silica gel. Where special drying agents are employed, they should be reactivated in accordance with specific instructions furnished by the manufacturer.



96.33

Figure 9-5.—Vacuum indicator readings plotted during dehydration.

After reactivation, the drying agent should be replaced in the dehydrator shell and sealed as quickly as possible, in order to prevent absorption of atmospheric moisture. When the drying agent becomes fouled or saturated with lubricating oil, it must be replaced by a fresh charge, or dehydrator cartridge, taken from a sealed container.

Remember that the dehydrators permanently installed in refrigeration systems of naval ships are designed to remove only the minute quantities of moisture unavoidably introduced in the system. Extreme care must be taken to prevent moisture, or moisture-laden air, from entering the system.

CLEANING THE SYSTEM

Systems may accumulate dirt and scale as a result of improper techniques used during repair or installation of the system. If such dirt is excessive and a tank-type cleaner is available, connect the cleaner to the compressor suction strainer. Where such a cleaner is not available, a hard wool felt filter, about 5/16 inch thick, should be inserted in the suction strainer screen. The plant should be operated with an operator in attendance, for at least 36 hours or until cleaned, depending upon the size and condition of the plant.

AIR CONDITIONING CONTROL

Most of the information presented to this point applies to the refrigeration side of a system, whether it is used for a refrigeration plant or for air conditioning. The compressor controls for both type systems are nearly indentical; however, the devices used to control space temperatures differ. The two-position dual control, called 2PD is used for the automatic control of most shipboard air conditioning systems.

TWO–POSITION DUAL CONTROL (2PD)

This control may be used on three types of systems:

1. Systems employing a simple thermostatically controlled single-pole switch to control ' of refrigerant to the cooling coil.

2. Systems using reheaters, employing a thermostatic element actuating two interlocked switches.

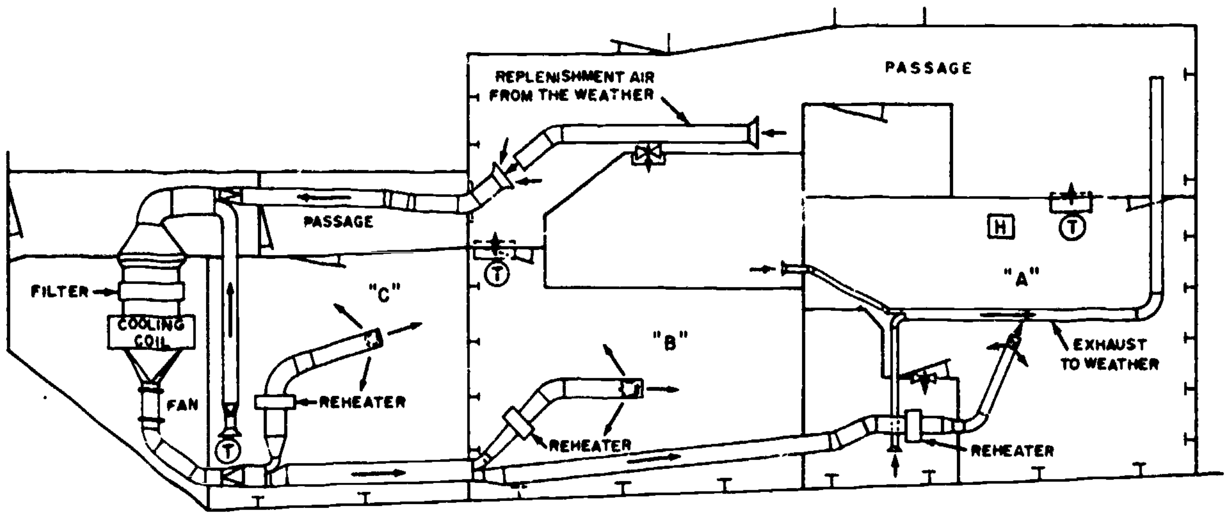
3. Systems using reheaters in the same manner as in item 2 with control of humidity added, where specified.

The type I system, because of its simplicity, requires little explanation. A thermostat, consisting of a temperature sending element, actuating a single-pole, single-throw switch, opens and closes a magnetic valve to start and stop the flow of refrigerant–chilled water or commercial refrigerant. This type of control is similar to thermostatic control for the refrigeration plant. Although the type I system requires single-pole thermostats, the 2 PD use in types 2 and 3 systems can be used. The cooling switch would then be connected in the normal manner with the heating switch inoperative.

The use of the type 2 system is most commonly used due to past and present efforts to make living and working spaces more habitable and to the rapid development of various types of weapons systems. Such spaces often use a common cooling coil serving several different spaces. Assume three spaces are being cooled by a common coil. Since the load changes seldom occur simultaneously, electric or steam reheaters are installed in the cooling air ducts. The cooling thermostat of the various spaces are connected in parallel so that any one may open the cooling coil valve.

Suppose space "B" figure 9-6 has a load change and spaces "A" and "C" do not. These spaces would become too cold for comfort with the coil operating to take care of space "B." In order to prevent this condition, the thermostat would close the heating switch and energize the reheaters for spaces A and C.

The type 3 system is identical to the type 2 system, except that a humidistat is wired in parallel with the thermostatic heating switch. This type system is used mostly in weapons and electronic spaces. The humidistat is set for the relative humidity condition desired. In most installations, it is only necessary to prevent the humidity from exceeding 55 percent. Where the humidistat is installed, an increase in temperature beyond the thermostat setting will close the



121.37

Figure 9-6.–Typical air conditioning system.

thermostat cooling switch. An increase in relative humidity beyond the humidistat setting will close the heating switch energizing the reheaters.

MAINTENANCE

Proper attention to the Planned Maintenance System often detect developing troubles in time to take corrective action. Since most breakdowns often occur at the most inopportune time, periodic checks and maintenance will prove to be well worthwhile to avoid malfunctions.

The two-position control system can easily be checked out in a reasonably short time. The checkout period should be at least every three months or more often if it proves to be necessary. Inspection and checks should be at the beginning of the cooling season and about midway, and the same for the heating season.

Sensing elements should be inspected and any dust accumulations removed. Thermostatic sensing elements may have dust and dirt removed with a soft brush, whereas sensing elements in humidistats must be blown off gently with air so as not to damage the element.

Magnetic valve should be checked for operation. Be sure that the valve is opening and closing completely.

Set points of the thermostats and humidistats should be checked with a calibrated thermometer and a reliable humidity indicator.

When servicing the two-position control system there are three possible sources of trouble.

1. The sensing element and its associated mechanism.

2. The magnetic valves that control the flow or refrigerant.

3. The wiring system which connects the sensing elements to the solenoids of the magnetic valves and the controller of the electric heaters.

DETECTING AND CORRECTING TROUBLES

Faulty operation of the refrigerating and air conditioning plants is indicated by various definite symptoms. Information in figures 9-7 and 9-8 presents some possible troubles that may be encountered, the possible causes of the troubles, and corrective action which may be taken.

Trouble	Possible Cause	Corrective Measure
High condensing pressure.	Air on non-condensable gas in system.	Purge air from condenser.
	Inlet water warm.	Increase quantity of condensing water.
	Insufficient water flowing through condenser.	Increase quantity of water.
	Condenser tubes clogged or scaled.	Clean condenser water tubes.
	Too much liquid in receiver, condenser tubes submerged in liquid refrigerant.	Draw off liquid into service cylinder.
Low condensing pressure.	Too much water flowing through condenser.	Reduce quantity of water.
	Water too cold.	Reduce quantity of water.
	Liquid refrigerant flooding back from evaporator.	Change expansion valve adjustment, examine fastening of thermal bulb.
	Leaky discharge valve.	Remove head, examine valves. Replace any found defective.
High suction pressure.	Overfeeding of expansion valve.	Regulate expansion valve, check bulb attachment.
	Leaky suction valve.	Remove head, examine valve and replace if worn.
Low suction pressure.	Restricted liquid line and expansion valve or suction screens.	Pump down, remove, examine and clean screens.
	Insufficient refrigerant in system.	Check for refrigerant storage.
	Too much oil circulating in system.	Check for too much oil in circulation. Remove oil.
	Improper adjustment of expansion valves.	Adjust valve to give more flow.
	Expansion valve power element dead or weak.	Replace expansion valve power element.

54.299.1

Figure 9-7.—Trouble diagnosis chart.

Trouble	Possible Cause	Corrective Measure
Compressor short cycles on low pressure control.	Low refrigerant charge.	Locate and repair leaks. Charge refrigerant.
	Thermal expansion valve not feeding properly. (a) Dirty strainers. (b) Moisture frozen in orifice or orifice plugged with dirt. (c) Power element dead or weak.	Adjust, repair or replace thermal expansion valve. (a) Clean strainers. (b) Remove moisture or dirt (Use system dehydrator). (c) Replace power element.
	Water flow through evaporators restricted or stopped. Evaporator coils plugged, dirty, or clogged with frost.	Remove restriction. Check water flow. Clean coils or tubes.
	Defective low pressure control switch.	Repair or replace low pressure control switch.
Compressor runs continuously.	Shortage of refrigerant.	Repair leak and recharge system.
	Leaking discharge valves.	Replace discharge valves.
Compressor short cycles on high pressure control switch.	Insufficient water flowing through condenser, clogged condenser.	Determine if water has been turned off. Check for scaled or fouled condenser.
	Defective high pressure control switch.	Repair or replace high pressure control switch.
Compressor will not run.	Seized compressor.	Repair or replace compressor.
	Cut-in point of low pressure control switch too high.	Set L.P. control switch to cut-in at correct pressure.
	High pressure control switch does not cut-in. 1. Defective switch. 2. Electric power cut off. 3. Service or disconnect switch open.	Check discharge pressure and reset H.P. control switch. 1. Repair or replace switch. 2. Check power supply. 3. Close switches.

54.299.2

Figure 9-7.—Trouble diagnosis chart—Continued

Trouble	Possible Cause	Corrective Measure
Compressor will not run. (Cont'd)	4. Fuses blown.	4. Test fuses and renew if necessary.
	5. Over-load relays tripped.	5. Re-set relays and find cause of overload.
	6. Low voltage.	6. Check voltage (should be within 10 percent of nameplate rating).
	7. Electrical motor in trouble.	7. Repair or replace motor.
	8. Trouble in starting switch or control circuit.	8. Close switch manually to test power supply. If OK check control circuit including temperature and pressure controls.
	9. Compressor motor stopped by oil pressure differential switch.	9. Check oil level in crankcase. Check oil pump pressure.
Sudden loss of oil from crankcase.	Liquid refrigerant slugging back to compressor crank case.	Adjust or replace expansion valve.
Capacity reduction system fails to unload cylinders.	Hand operating stem of capacity control valve not turned to automatic position.	Set hand operating stem to automatic position.
Compressor continues to operate at full or partial load.	Pressure regulating valve not opening.	Adjust or repair pressure regulating valve.
Capacity reduction system fails to load cylinders.	Broken or leaking oil tube between pump and power element.	Repair leak.
Compressor continues to operate unloaded.	Pressure regulating valve not closing.	Adjust or repair pressure regulating valve.

54.200.3

Figure 9-7.—Trouble diagnosis chart—Continued

TROUBLE	POSSIBLE CAUSE	TEST	REMEDY
Space temperature higher than thermostat setting	Bad location of thermostat	Carefully read temperature at the sensing element	Relocate thermostat to a place more representative of average space temperature
	Thermostat out of adjustment or sticking	Calibrate with good thermometer	Clean, adjust, or replace the thermostat
	Cooling coil magnetic valve not opening	Solenoid Valve Valve sticking	Replace solenoid coil.Clean valve or adjust pilots.
Space temperature lower than thermostat setting	Bad location of thermostat (this will also affect cooling)	Test with reliable thermometer at location	Move thermostat to a better location.
	Cooling coil magnetic valve stuck in open position	Stuck valve	Disassemble and clean.
	Heating coil magnetic valve stuck or bad solenoid	Test solenoid. Test valve.	Replace solenoid coil. Clean the valve.
Thermostat or humidistat time constant too long, causing wide deviation from set point	Sensing element fouled with lint and dirt	Examine	Clean.
Electric heater does not cut out	Controller contacts stuck	Use test lamp to determine	Replace contacts, springs or other parts as found defective.
Electric heater does not cut in	Overheat protection not reset or defective	Place test lamp across	Repair or replace.

121.38

Figure 9-8.–Trouble diagnosis chart.

CHAPTER 10

AUXILIARY EQUIPMENT

This chapter provides general information on the care and maintenance of steering and hoisting mechanisms, hydraulic systems, and compressed air systems.

STEERING GEAR

Aboard modern naval vessels, practically all steering mechanisms are hydraulically driven. Since you may be responsible for maintenance or repairs on steering gears, particularly on variable-stroke hydraulic pumps and other component parts of the hydraulic system, you should familiarize yourself with this type of equipment. Your best source of information will be the manufacturers' instruction books.

REMOTE CONTROL

The remote control of steering gears on most modern ships is accomplished electrically, by means of alternating-current synchronous transmission. However, you may encounter some systems in which remote control is accomplished hydraulically by means of a telemotor system.

THE HYDRAULIC TELEMOTOR type of remote control is installed aboard many auxiliary ships of the Navy. On this type of control, maintenance usually consists of nothing more than the prevention of leaks in the hydraulic system and the proper care of the fluid.

Frequent inspections of the valves and joints will greatly help in eliminating and preventing leaks in the system. If the piston of an internally packed telemotor is leaking, check the condition of the leathers and make certain the springs, if installed, keep the leather in contact with the inside wall of the telemotor cylinders. Leaks in externally packed telemotor can usually be stopped by tightening the glands just enough to cause the packing to be compressed about the rams.

HYDRAULIC RAMS

Since portions of the rams in an electrohydraulic steering gear are exposed where they fit into the cylinders, it is necessary to take precautions against possible damage to such surfaces. The exposed surfaces of rams should not be used as walkways. In addition, they should be protected from water and from rolling or falling objects, and should be kept clean, smooth, and lightly coated with fluid at all times. Frequent inspections should be made during operation, in order to detect any evidence of damage. A guard placed over the exposed parts will offer protection against rolling objects, and the compartment should be kept free of loose gear that might slide into the rams. If burrs or scratches on the ram are noticed, they should be smoothed out with a fine whetstone as soon as possible. If rams are severely scored, corroded or damaged, the rams should be removed and refinished. If considerable material is removed from the rams in order to obtain a good finish, the cylinder bushings and packings must be replaced.

Ram packings should be kept sufficiently tight to prevent observable leakage but loose enough to allow a light film of fluid to remain on the plunger as it emerges from the cylinder. Overtightening should be avoided, since excessive pressure usually increases friction and shortens packing life.

The oil in the high pressure hydraulic system of a steering gear should be filtered in accordance with Planned Maintenance System. Poor filtering results in the accumulation of foreign matter injurious to the rams and to the variable stroke pumps. Make-up oil should be filtered before it is added to the system. When the system is drained into the base tank, accumulated foreign matter can be filtered out by pumping the oil through the filters to the expansion tanks. The oil is then drained back into the storage tanks and the system refilled with the filtered oil.

ANCHOR WINDLASSES

Even though used intermittently and only for relatively short periods of time, a windlass must be capable of handling the required load under extremely severe conditions. To prevent deterioration and to provide dependable operation whenever required, maintenance and adjustment must be continued during the periods when the machinery is not in use.

Windlass brakes (electric and handbrake) must be maintained in satisfactory condition if they are to perform their function properly. Because of wear and compression of brake linings, the clearance between the brake drum and band will increase after a windlass has been in operation. Means of adjustment are provided on all windlass brakes. Since maladjustment of a windlass brake could result in the loss of the anchor and chain, it is advisable that you become familiar with maintenance procedures.

Lubrication instructions should be carefully followed. If a windlass has been idle for some time, lubrication of the equipment should be accomplished before operation is attempted. After a windlass has been used, the equipment should be lubricated to protect finished surfaces from corrosion.

The hydraulic transmissions of electrohydraulic windlasses and other auxiliaries are manufactured with close tolerances between moving and stationary parts. If these tolerances are to be maintained and unnecessary wear prevented, every precaution possible must be taken to prevent the entry of dirt and other abrasive material. When the system is replenished or refilled, only clean oil should be [illegible]d and the oil should be strained as it is poured into the tank. If a hydraulic transmission has been disassembled, all parts should be thoroughly cleaned before reassembly. Before piping or valves are installed, their interiors should be cleaned to remove any scale, sand, or other foreign matter.

WINCHES AND CRANES

In several respects, the maintenance of a winch is similar to that of a windlass. The drum brake on winches and cranes will normally see very little wear since it is normally applied when the load has stopped moving. The electric or hydraulic brake mounted on the input shaft of [illegible] gear box of the winch or crane receives essentially all the wear and should be inspected regularly and repaired when necessary. Steps should be taken to prevent oil or grease from accumulating on the brakes. The operation of brake-actuating mechanisms, latches, and pawls should be checked periodically.

The sliding parts of positive clutches must be properly lubricated, and the locking device on the shifting gear should be checked to determine if it will hold under load. The oil of gear reduction units should be checked for proper amount and purity. Periodic inspections should be made of the pressure lubrication fittings normally installed on slow-moving parts. On installations which use hydraulic transmission, the pumps and lines are maintained in the same way as those of any other hydraulic system.

As with many other auxiliary units, the winches and cranes you maintain may be driven by hydraulic transmissions, by electric motors, by Diesel engines, or by hand. Maintenance should be accomplished in accordance with Planned Maintenance System. In general, the maintenance of electrohydraulic cranes requires that the oil in the replenishing tanks be kept at the prescribed levels, and that the system be kept clean and free of air. The limit stop and other mechanical safety devices must be checked regularly for proper operation. When cranes are not in use, they should be secured in their stowed positions and all electric power to the crane controllers disconnected at the power distribution panel.

ELEVATORS

Carriers are provided with two or more electrohydraulic elevators, capable of handling airplanes between the flight and hangar decks at relatively high speed. As an MM1 or C, you may not be called upon too frequently to maintain this type of machinery. However, if you are required to maintain electrohydraulic elevators, you will find maintenance procedures relatively the same as for other auxiliaries which use fluid to transmit power.

Elevator cables and fittings should be inspected frequently, and the tension of the cables in each group kept equal. Frequent inspections must be made to ensure that (1) there is proper oil level in the pressure and exhaust tanks. (2) there is no excessive leakage in the sump leak-off connections, (3) the pistons seal properly in the hydraulic cylinders, and (4) the entire system is clean.

HYDRAULIC SYSTEMS

The over-all efficiency of hydraulic installations used to control or drive auxiliary machinery is basically dependent upon size of installation, oil pressure, speed, and condition of the equipment. The care given the hydraulic components of the system is an important factor. Major repair of hydraulic gear, except for piping and fittings, is generally performed at a naval shipyard or by the manufacturer. Routine maintenance, keeping the oil clean, and maintaining proper fluid levels is the responsibility of the operator.

Hydraulic transmissions are sturdy, proven machines, inspected and tested with such care that casualties seldom occur except as a result of faulty assembly, installations, or maintenance. If a properly installed hydraulic system is operated regularly and maintained with proper care, it will retain its design characteristics of power, speed, and control, and the need for costly repair and replacement will seldom occur.

MAINTENANCE

Regular operation, proper lubrication. proper maintenance of all the units, and cleanliness of the fluid are principal requirements for keeping a hydraulic transmission in satisfactory operating condition. Regular operation of hydraulic equipment prevents corrosion, sludge accumulation, and freezing of adjacent parts. The need for proper lubrication and cleanliness cannot be too strongly emphasized.

Detailed instructions concerning the maintenance of a specific unit may be obtained from the Planned Maintenance System and appropriate instruction book; however, the general information which follows will also be helpful.

Piping and Fittings

Properly installed hydraulic piping and valves are seldom a source of trouble, except for leakage. Some leaks may become serious enough to cause a reduction in the efficiency of the unit(s). Frequent inspections should be made and necessary steps taken to eliminate leakage.

If leaks occur at a flanged joint in the line of a hydraulic system, tighten the flange bolts evenly, but not excessively. If the leaks persist, use the standby unit, if available, or shut down the equipment while the gasket of the leaking flange is being replaced. Make certain that the flange surfaces are cleaned carefully before the gasket is applied. NOTE: Fittings should not be tightened while the system is pressurized.

Relief valves or shuttle valves of a hydraulic system may be sources of trouble. The seats of leaking relief valves should be reground. Loss of power may indicate a leaking relief valve. Shuttle valves may stick and fail to cut off. Existence of this condition is indicated when oil escapes from the high-pressure side of the line into the expansion tank, or when the pressure control fails. When a shuttle valve fails to operate, the stop valves should be closed and the defective valve removed for repair.

Fluid System

When inspection of an oil sample drawn from a hydraulic system reveals the presence of metal particles, water, sludge, acidity or other contaminants the system must be drained, flushed and refilled in accordance with current applicable Navy procedures for the particular system. The presence of foreign particles in the hydraulic system indicates a possible component malfunction, which should be corrected prior to flushing the system.

Hydraulic fluid which has been contaminated by use as the working fluid or as a flushing medium must not be used again, but should be disposed of according to prevailing instructions.

Pumps and Motors

An electric motor is provided to rotate the hydraulic pump. Oil under pressure is delivered from the pump to the hydraulic motor of the variable speed transmission through piping. The hydraulic motor rotates the individual unit or equipment through suitable reduction gearing. Whether the pumps and motors of hydraulic transmissions are of the axial or radial piston type, maintenance procedures and operating principles are relatively the same. In general, maintenance information on other type pumps also applies to hydraulic pumps and motors.

On modern hydraulic transmissions, shaft packing material are of five general classifications: synthetic rubber, fluorinated compounds, silicones, fabric and rubber combinations, and leather. The hydraulic fluid to be sealed determines the type of packing material to be used. Packings for use in hydraulic systems containing petroleum base fluid cannot be used in systems using phosphate ester fluids and vice versa. Water-glycol type fire resistant fluids and water-petroleum oil emulsion fluids are generally compatible with any packings designed for petroleum oil.

The success or failure of any packing material depends upon more than compatibility of the fluid and the packing material. Other considerations are such factors as pressures, shock loads, clearances, surface finishes, temperatures, frequency and duration of work cycles, in order to prevent excessive wear or frictional load. Packings should be installed in the sequence and direction given in applicable instruction manuals, or as the old ones were removed. Packing glands should only be tightened to the degree that leakage is kept to acceptable levels. Overtightening increases friction and shortens packing life.

There is less likelihood of POOR ALIGNMENT BETWEEN THE DRIVING AND DRIVEN MEMBERS of a hydraulic transmission if the wedges, shims, jacking screws, or adjusting setscrews are properly set and secured when connected units are installed. However, because of a casualty, misalignment may occur that will cause severe stress and strain on the coupling and connected parts. Misalignment should be eliminated as soon as possible by replacing any defective parts and readjusting the installed aligning devices. If this is not done, pins, bushings, and bearings will have to be replaced frequently.

Since there is no end play to either the pump or motor shaft, flexible couplings are generally used in hydraulic transmissions. Such couplings permit satisfactory operation with a slight misalignment, without requiring frequent renewal of parts.

TROUBLESHOOTING

In attempting to locate the source of any trouble in an electrohydraulic system, remember that all troubles which occur will be in one of three categories–hydraulic, electric, or mechanical. Isolating a trouble into one of these categories is one of the primary steps in locating the source of trouble.

Hydraulic Casualties

These casualties are generally the result of low oil levels, external or internal leakage, clogged lines or fittings, or improper adjustment of valves and other working parts. Do not disassemble a unit unless certain that the trouble exists within that unit. Unnecessary disassembly can lead to additional trouble, because of the dirt which may enter an open system.

Leaks are a frequent cause of trouble in hydraulic equipment. Leaks are generally caused by excessively worn parts, by abnormal and continuous vibration, by excessively high operating pressures, or by faulty or careless assembly. External leaks usually have little effect on the operation of equipment other than a steady draining of the oil supply; but even a small leak wastes oil, and the resulting unsightly appearance of a machine is indicative of poor maintenance procedures.

External leaks may result from any of the following causes: improperly tightened threaded fittings; crossed threads in fittings; improperly fitted or damaged gaskets; distorted or scored sealing rings, oil seals, or packing rings; scored surfaces of working parts; improperly flared tube ends; or flanged joints not sealing squarely.

Internal leaks, however, generally result in unsatisfactory operation of the equipment. Large internal leaks are indicated by loss of pressure and failure of equipment. While large internal leaks can usually be located by installing a pressure gage in various parts of the equipment, the location of small leaks generally requires disassembly and visual inspection of the parts. Internal leaks may result from worn or scored valves, pistons, valve plates, or bushings; or from improperly fitted or damaged gaskets.

The symptoms of trouble in a hydraulic system are frequently in the form of unusual noises. Some noises are characteristic of normal operation and can be disregarded, while others are evidence of serious trouble. Even though the exact sound indicating trouble can be learned only through practical experience, the following descriptive terms will give a general idea of the noises which are trouble warnings.

The occurrences of POPPING and SPUTTERING noises is an indication that air is entering the pump intake line. Air entering the system at this point may be the result of too small an intake pipe, an air leak in the suction line, a low oil level in the supply tank, cold or heavy oil, or possibly the use of improper oil.

If air becomes trapped in a hydraulic system, HAMMERING will occur in the equipment or in the transmission lines. If hammering occurs, check for improper venting. In some cases, a POUNDING or RATTLING noise occurs as a result of a partial vacuum produced in the active fluid during high-speed operation or when a heavy load is applied. This noise may be unavoidable under the conditions stated and can be overlooked if it stops when speed or load is reduced. If the noise continues at low speeds or light loads, the system should be vented of air. Air in a hydraulic system can also cause uneven motion of the hydraulic motor.

The cause of a GRINDING noise is most likely to be dry bearings, foreign matter in the oil, worn or scored parts, or overtightness of some adjustment.

The term HYDRAULIC CHATTER is sometimes used to identify noises caused by a vibrating spring-actuated valve, by long pipes improperly secured, by air in the lines, or by binding of some part of the equipment.

If the packing is too tight around some moving part, SQUEALS or SQUEAKS may occur. This type of noise might also indicate that a high-frequency vibration is occurring in a relief valve.

Electrical Casualties

Although the EM is responsible for checking electrical equipment troubles, the MM can facilitate maintenance of electrical equipment by making a few simple tests when electrical troubles occur. Such an oversight as not having a switch in the ON position may be the reason for equipment failing to operate. If the circuit is closed and the equipment still fails to operate, check for blown fuses and tripped circuit breakers. These troubles generally result from an overload on the equipment. If a circuit breaker continues to cut out, the trouble may be damaged equipment, excessive binding in the electric motor, obstruction in the hydraulic transmission lines, or faulty operation of the circuit breaker. Another source of electrical troubles may be in the circuit; check for open or shorted leads, faulty switches, and loose connections.

Mechanical Casualties

When an electrohydraulically driven auxiliary becomes inoperative because of a mechanical failure, a check should be made for improper adjustment or misalignment of parts, shearing of pins or keys, or breakage of gearing, shafting or linkage. Elimination of troubles resulting from any of these causes should be accomplished in accordance with the manufacturer's instructions for the specific equipment.

COMPRESSED AIR SYSTEMS

As an MM3 or 2, you used compressed air for blowing out and cleaning various units, and for operating numerous pneumatic tools. In working with any of the three types of compressed air systems (low-, medium-, and high-pressure), you probably found that the primary source of any trouble was the compressor. Although the design and capacity of compressors vary, the maintenance procedures are essentially the same. However, remember that the care and maintenance of high-pressure compressors require additional safety precautions, and the procedures recommended by the manufacturer should be followed.

Some portions of the discussion which follows may serve as a review. Other portions of the discussion should be beneficial in your study for advancement, and helpful when you are called upon to train men.

While modern auxiliary machinery is rugged and dependable, it is not designed to withstand abusive treatment. Gasketed joints, pipe joints, and bolts are designed to safely withstand the strain required for a tight connection when the specified torque is applied with the correct tool. The application of a force in excess of that prescribed usually results in breakage. If a joint or bolt cannot be tightened without using an oversized wrench or wrench handle extension, there will probably be something wrong with the assembly.

CARE AND MAINTENANCE OF AIR COMPRESSORS

The over-all problem in maintaining compressed air systems is to take the necessary steps to prevent a reduction in compressor capacity. To keep a ship's air compressor operating efficiently at all times and to prevent as many troubles as possible, it is necessary to know how to care for air intakes and filters; how to maintain and replace air valves; how to take care of air cylinders, pistons, and wrist pins, how to adjust bearings, couplings, etc.; and how to properly maintain the lubrication, cooling, control, and air systems.

Air Intakes and Intake Filters

Satisfactory operation of any compressor ...res a supply of clean, cool, dry air. To help ... the air supply clean, filters are fitted to compressor intakes. Unless these filters are inspected and cleaned regularly they will become clogged and cause a loss of capacity.

To clean filter elements remove them from the intake and wash them with a jet of hot water or steam, or immerse them in a strong solution of washing soda. The filter body should be drained and replaced. Filter elements of the oil-wetted type should be dipped in clean oil after cleaning. Before replacing the element in the intake, let excess oil drain from it. The use of gasoline or kerosene is prohibited for cleaning air filters, because of explosive fumes which may collect in the compressor or air receiver.

Air Valves

The inlet and discharge valves of compressors require special attention. When valves leak, compressor capacity is reduced and pressure is affected. Deviation from normal intercooler pressure may indicate a leaking or broken valve; rise in pressure indicates a defective inlet valve; decrease in pressure indicates a defective discharge valve. Another sign of valve trouble is an unusually hot valve cover.

Dirt is generally the cause of leaking valves. When valves become dirty, the source of trouble can usually be traced to dirty intake air; use of an excessive amount, or of an improper grade, of cylinder oil; or excessively high air temperature, resulting from faulty cooling. Periodic inspection and cleaning of valves and valve passages minimizes the number of air valve troubles.

When air valves are removed for inspection, mark each valve to ensure that it will be replaced in the same opening from which it was removed. Inspect valves carefully and do not disassemble them for cleaning unless their condition necessitates such action. Dirt or carbon can usually be removed from valve parts without disassembling the valve. If it becomes necessary to disassemble the valve, note the arrangement of the various parts so that the proper relationship will be kept when the valve is reassembled. To remove carbon from valve parts, soak the individual part in a suitable solvent and then brush or scrape lightly. After drying and reassembling the valve parts, test the operation of the valve to see if it opens and closes freely.

Before replacing air valves in a cylinder, inspect the gaskets. If other than copper, replace any which are damaged. Copper gaskets should always be replaced. Since it may be difficult, in many cases, to distinguish between suction and discharge valves, extreme care must be taken when the valves are being inserted in the cylinder. Make certain that suction valves open TOWARD, and discharge valves AWAY FROM, the center of the cylinder; otherwise serious damage or loss of capacity will result. In most instances, special lock nuts are provided to seal against leakage at the threads of the valve setscrew.

Cylinders, Pistons, and Related Parts

You should be familiar with the safety precautions to be followed in maintaining an air compressor, and with the procedures for cleaning cylinders, removing pistons, fitting new piston rings, replacing cylinders, checking piston end clearances, adjusting bearings, replacing wrist pins, packing stuffing boxes, and caring for couplings and V-belts. It is essential, therefore, to consult the maintenance procedures as recommended by the manufacturer.

Control Devices

Because of the great variety of control, regulating the unloading devices used with compressors, detailed instructions on their adjustment and maintenance must be obtained from manufacturer's instruction books.

If a control valve fails to operate properly, disassembly and a thorough cleaning will usually be necessary. Some control valves are fitted with filters filled with sponge or woolen yarn, to prevent dust and grit from being carried into the valve chamber. These filters also remove the gummy deposit which comes from the oil used in the compressor cylinders. The filter element should be replaced with the specified material each time a valve is cleared. Do not use cotton, because it will pack down and stop the air flow.

Since relief valves are necessary to ensure safe operation of a compressed air system, they must be maintained in satisfactory operating conditions at all times. Relief valves should be set as specified by the manufacturer. They should be tested by hand each time the compressor is started, and the valve setting should be checked periodically by raising the pressure in the spaces to which the valves are attached. Chapter 15 of *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D contains information on the principles of operation of reciprocating air compressors.

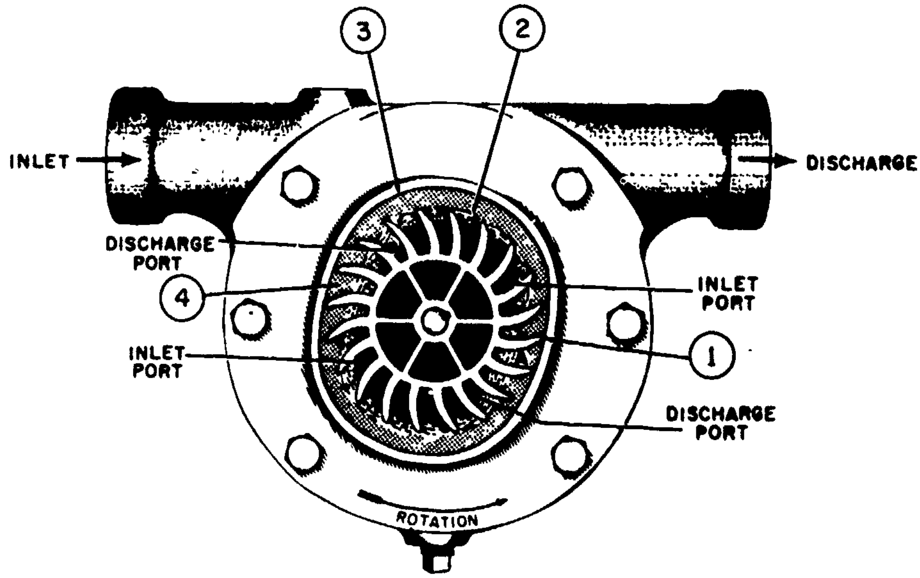
ROTARY-CENTRIFUGAL AIR COMPRESSORS

The one non-reciprocating type of air compressor that is found aboard ship is variously referred to as a rotary compressor, a centrifugal compressor, or a "liquid piston" compressor. Actually, the unit is something of a mixture, operating partly on rotary principles and partly on centrifugal principles; most accurately, perhaps, it might be called a rotary-centrifugal compressor.

The rotary-centrifugal compressor is used to supply low pressure compressed air. Because this compressor is capable of supply air that is completely free of oil, it is often used as the compressor for pneumatic control systems and for other applications where oil-free air is required.

The rotary-centrifugal compressor, shown in figure 10-1, consists of a round, multibladed rotor which revolves freely in an elliptical casing. The elliptical casing is partially filled with high-purity water. The curved rotor blades project radially from the hub. The blades, together with the side shrouds, form a series of pockets or buckets around the periphery. The rotor, which is keyed to the shaft of an electric motor, revolves at a speed high enough to throw the liquid out from the center by centrifugal force, resulting in a solid ring of liquid revolving in the casing at the same speed as the rotor but following the elliptical shape of the casing. This action alternately forces the liquid to enter and recede from the buckets in the rotor at high velocity.

To follow through a complete cycle of operation, let us start at point A. The chamber (1) is full of liquid. The liquid, because of centrifugal force, follows the casing, withdraws from the rotor, and pulls air in through the inlet port. At (2) the liquid has been thrown outward from the



147.119

Figure 10-1.—Rotary—centrifugal compressor.

chamber in the rotor and has been replaced with atmospheric air. As the rotation continues, the converging wall (3) of the casing forces the liquid back into the rotor chamber, compressing the trapped air and forcing it out through the discharge port. The rotor chamber (4) is now full of liquid and ready to repeat the cycle which takes place twice in each revolution.

A small amount of seal water must be constantly supplied to the compressor to make up for that which is carried over with the compressed air. The water which is carried over with the compressed air is removed in a refrigeration-type dehydrator.

CARE AND MAINTENANCE OF AIR SYSTEM EQUIPMENT

Surface Inspections and Maintenance

The air flasks, high pressure piping, and separators are inspected in accordance with the Planned Maintenance System. These inspections are made to determine if there is any external corrosion or damage to flasks or piping. Air flasks must be blown down weekly. Moisture separators installed down stream of the compressor must be blown down hourly during operation of the compressor. Filter elements must be changed in accordance with existing instructions.

The drainage of air system equipment must be sufficiently frequent to prevent excessive accumulations of moisture and oil. Such accumulations not only cause internal corrosion and fouling of moving parts, but also create a serious hazard in that excessive oil accumulation may cause an explosion.

Inspection, Cleaning, and Testing by Repair Activities

In addition to shipboard inspection and maintenance of high-pressure air flasks and separators, there must be an inspection, cleaning, testing, and repainting performed at prescribed intervals by a repair activity. For surface vessels the initial and subsequent intervals should not exceed six years. Inspection intervals for separator flasks should be approximately every three years. However, if there is reason to believe that serious corrosion is taking place in either the exteriors or interiors of air flasks, inspection should be made before the elapse of the normal interval.

The periodic examinations should include not only a complete examination of the interior and exterior surfaces of flasks and separators, but a thorough cleaning, ultrasonic inspection, and the performance of hydrostatic tests. Flasks which pass the hydrostatic test are given the prescribed internal protective coating, and the exterior surfaces are painted if necessary. Detailed information on the inspections and maintenance performed by naval shipyards can be found in the *Naval Ships Technical Manual*.

INSPECTIONS AND MAINTENANCE

Minimum requirements for the performance of inspections and maintenance on high pressure air plants are shown on the maintenance index page, figure 10-2.

It is the responsibility of the engineer officer to determine if the condition of the equipment, hours of service, or operating conditions necessitate more frequent inspections and tests. Details for outline tests and inspections may be obtained from the appropriate manufacturer's instruction book or from the *Naval Ships Technical Manual*.

SAFETY PRECAUTIONS

There are many hazards associated with the process of air compression. Serious explosions have occurred in high pressure air systems because of a diesel effect. Ignition temperatures may result from rapid pressurization of a low pressure dead end portion of the piping system, malfunctioning of compressor after coolers leaky or dirty valves, and many other causes. Every precaution must be taken to have only clean, dry air at the compressor inlet.

Air compressor accidents have also been caused by improper maintenance procedures such as disconnecting parts while they are under pressure, replacing parts with units designed for lower pressures, and installing stop valves or check valves in improper locations. Improper operating procedures have also caused air compressor accidents, with resulting serious injury to personnel and damage to equipment.

In order to minimize the hazards inherent in the process of compression and in the use of compressed air, all safety precautions outlined in the manufacturers' technical manuals and in the *Naval Ships Technical Manual* must be strictly observed.

STEAM WHISTLES

Since you may have to supervise the maintenance and repair of steam whistles installed on your ship, you should be familiar with the installation and maintenance of these units.

The diaphragm type of steam whistle is typical of the type used on modern ships. Before testing the whistle, remove the diaphragm leaves by unscrewing the back cover, and turn on the steam at least 30 minutes, with all drains open and traps operating. With the diaphragm removed, operate the whistle valve several times in order to blow out the pipe lines thoroughly. Replace the proper number of leaves and tighten the back cover before testing. The leaves are marked so that they may be installed properly; all leaves must have the high side facing towards the nozzle.

If water comes out through the horn or around the stem of the operating valve while the whistle is being tested, or if the note is not clear from the beginning of the first blast, immediately check all associated traps. If the traps are not functioning properly, they should be bypassed until put into working order.

The diaphragm of a steam whistle must be inspected and cleaned in accordance with maintenance procedures. Damaged leaves must be removed and replaced. After the leaves have been cleaned and positioned properly, the whistle must be retested.

The operating valve should also be checked when the diaphragm is examined. If the operating valve is leaking, it should be removed and ground in to obtain a good clean seat. The seat is generally locked in place with a setscrew and can be removed only with a proper wrench and after the setscrew has been loosened.

On the installation of a whistle valve, the following factors should be considered:

1. Steam supply must be taken either directly from a boiler or from a point on a steam line

System, Subsystem, or Component	Reference Publications
High-Pressure Air Compressor	

Bureau Card Control No.					Maintenance Requirement	M.R. No.	Rate Req'd.	Man Hours	Related Maintenance
AP	ZZZFCH1	35	4935	W	1. Operate compressor by power. 2. Blow down all air flasks, separators, and filters. 3. Sample and inspect lube oil.	W-1	MM2	0.5	None
AP	ZZPFVA1	84	4936	M	1. Lift relief valves by hand.	M-1	MM3	0.1	None
AP	ZZZFCH1	65	4937	Q	1. Clean suction filter. 2. Test inlet and outlet valves by operation. 3. Test temperature switch by operation. 4. Test automatic start and stop switch by operation.	Q-1	MM2	0.5	None
AP	ZZZFCH1	65	9223	Q	1. Test operation of speed-limiting governor and overspeed trip. 2. Test operation of temperature control.	Q-2	MM2 FN	1.0 1.0	None
AP	ZZZFCH1	65	7659	A	1. Clean lubricator reservoir.	A-1	FN	0.3	None
AP	ZZDFCU0	55	A142	C	1. Clean and test air coolers and oil cooler. 2. Inspect internal parts for wear.	C-1	MM1 FN	24.0 24.0	None
AP	ZZPFVA1	84	4941	C	1. Test relief valves by pressure.	C-2	FN	1.3	None
AP	ZZ6FTRO	25	7652	C	1. Clean, inspect, and preserve exterior of turbine casing.	C-3	MM3	1.0	C-4
AP	ZZ6FTRO	25	7656	C	1. Inspect carbon packing for wear.	C-4	MM1 MM3	4.0 4.0	C-3
AP	ZZZFPGF	85	2894	C	1. Inspect high-pressure air system for oil contamination.	C-5	MM2 FN	1.5 1.5	W-1

MAINTENANCE INDEX PAGE
OPNAV FORM 4700-3 (6-64)

BUREAU PAGE CONTROL NUMBER A-3/16-95

98.171

Figure 10-2.—Maintenance Index Page.

where there is a continuous flow of steam at all times.

2. There must be no horizontal piping between the whistle and the point where the steam supply line is connected.

3. A drain must be installed at the lowest point of a long lead of piping below decks.

4. The drain line from the whistle must be connected to a continuous flow trap connected to the atmosphere (never to the high-pressure drains).

CHAPTER 11

ADMINISTRATION, SUPERVISION, AND TRAINING

The higher you go in the Navy, the more responsibility you will have for administration, supervision, and training. This chapter deals briefly with some of your administrative and supervisory responsibilities and then takes up certain aspects of your responsibility for training others.

Although it is possible to consider administration, supervision, and training as three separate areas of responsibility, it is important to remember that the three things cannot be totally separated, Much of your work requires you to administer, supervise, and train, all at the same time. For example, consider a pump overhaul job. As an administrator, you will schedule the job, check on the history of the pump, and see that the required entries are made in appropriate logs and records. As a supervisor, you will actually oversee the work and make sure it is done correctly. As a trainer, you will provide information and instruction on repair parts, repair procedures and policies, safety precautions, and other matters.

These administrative, supervisory, and training tasks have a direct relationship to the job at hand—namely, the overhaul of the pump But the pump overhaul job can't even get started unless a variety of administrative, supervisory, and training functions are performed on a continuing basis. Materials, repair parts, and tools must be available when they are needed; jobs must be scheduled with due regard to the urgency of other work; records must be kept and reports must be submitted; and personnel must be in a continuous state of training so that they can assume increasingly important duties and responsibilities. The only way to keep things running smoothly is to take your administrative, supervisory, and training responsibilities seriously.

ADMINISTRATION AND SUPERVISION

As a Machinist's Mate, you will have administrative and supervisory responsibilities in connection with engineroom operations and in connection with engineroom maintenance and repair.

The engineering department administrative organization is set up to provide a means for the proper assignment of duties and for the proper supervision of personnel. However, no organization can run itself. Personnel—including you—are needed to see that all pertinent instructions are carried out; that all machinery, equipment, and piping systems are operated in accordance with good engineering practice; that operating instructions and safety precautions are posted by machinery and obeyed by all engineroom personnel; that all watchstanders are properly supervised; that records and reports are filled in correctly and submitted as required; and that the entire engineering plant is operated with maximum reliability, efficiency, and safety.

The experienced petty officer will soon learn that administration and supervision are very closely related. The administrator's and supervisor's role requires that he be a leader, a man of common sense, and a man who earns the respect of others. Many decisions are difficult to make. To be effective in his decision making, the supervisor assembles pertinent facts, policies, and procedures; develops a course of action and evaluates possible alternatives; selects the best course of action; and initiates the required action. When necessary, he consults his own superior prior to taking action. Every supervisor must face problems squarely and make timely and sound decisions. The supervisor who dodges his responsibilities will soon find his control of subordinates slipping away, discipline deteriorating, dissatisfaction with his supervision increasing and effectiveness of the organization suffering.

The supervisor who establishes and maintains a spirit of cooperation within his division and in the everyday dealings with other divisions and shops will find his job is much easier. Ship's readiness is the common purpose of the maintenance organization, and all ratings should share a common interest in achieving that purpose. A willingness by each individual to submerge his personal interest in favor of getting the job done is a necessary prerequisite to cooperation. If the supervisor's requests are reasonable, made well in advance (when possible), were understood, and provided all necessary information, his requests will generally induce cooperative action. If cooperation is lacking, check the facts to find out why. If subordinates are at fault, they can be told directly and in a firm manner, taking into consideration the basic principles of good leadership.

The supervisor's duties involve planning, direction, and control. Careful planning is an essential ingredient to effective supervision and minimizes other types of supervisory efforts when carefully executed. Time and effort invested in the process of careful planning is rarely wasted. It can result in job simplification and increased efficiency.

The effective supervisor initiates the planning process by identifying each specific job to be done by his men. With a rountine clearly established, he can spend his time on the exceptions that may arise. He knows the capacities, interests, weaknesses, and potentials of his men. Knowing each man's level of technical skill, motivation, ambitions, and personality characteristics will enable the supervisor to (1) assign the right man to the right job, (2) identify the training needed by each man to do a better job, and (3) establish the standard at which each man can be expected to perform.

Once action has been initiated, the supervisor provides direction. This function of supervision is like that of a "foreman." He sees that work is started and knows what is going on at all times. This does not mean that he must always be physically present while the job is being done. Subordinates should be trained to assume responsibility for the job in the absence of the supervisor so that no man is indispensable, including the supervisor. The supervisor should, however, be available when his men are working, and they should know how to contact him. The supervisor should always be present when his men are assigned new tasks, when they have trouble getting a job done, or when other circumstances dictate the necessity for his presence. He must be careful not to oversupervise lest he destroy the initiative of his workers and subordinate supervisors. He receives suggestions and reactions from his subordinates and acts as necessary on them, giving credit when and where it is due. Recognition of each man as an individual is required.

Control of a job refers to the function of checking to see that the job is done as planned—a comparing of performance with plans. Deviations may reflect poor planning. However, procedures should exist whereby changes in plans that could result in improved performance can be implemented to minimize repetition of faulty performance.

The supervisor will be challenged to allocate sufficient time to be expended on planning, direction, and control. A spirit of firmness, fairness, cooperation, decisiveness, harmony, and mutual respect while seeing that the job is done will rarely go unrewarded.

COMMUNICATIONS

The area of communications as related to administration and supervision is singled out here because of its importance. Almost without exception, problem areas regardless of their nature can be attributed to the lack of proper communications. Men like to be kept informed about all the things that affect them. Keeping them informed will improve their morale and generally make them more responsive to the needs of the command. The supervisor can improve morale by keeping his men as well informed as possible concerning need-to-know and nice-to-know information that could affect them, as long as it is not classified.

Communications is a two-way process. The supervisor must be able to convey his ideas, orders, etc., and pass on information, either orally or in writing, in such a manner that it will be clearly understood. He must also be willing to listen to and try to understand the ideas of others. Subjectivity (that is, looking at things only from a personal viewpoint, because of your position, rating, pay grade, or any other reason) will hinder communications. Bias and limited knowledge can limit a supervisor's ability to be objective, and by recognizing this fact, he can listen more objectively.

Ridicule, sarcasm, vulgarity, etc., have no place in good communications. The supervisor who must get loud and resort to such language to get his point across or the job done needs to realize how adversely such action affects his own feelings of importance and respect. When it becomes necessary to orally reprimand a subordinate, do it in private, keeping in mind that he is an individual and as a petty officer he must have the respect of the men under him. If a supervisor reprimands a man in public, both lose respect and are less effective in getting the job done.

PROFESSIONALISM

It is the responsibility of all senior petty officers to instill a spirit of professionalism in their subordinates. Ship maintenance is a reasonably complicated profession that leaves little room for error. The maintenance man who gives it less than his undivided attention presents a potential hazard. Of primary importance are the ethical attitudes and considerations involved in performing each maintenance task, the unspoken but carefully adhered to codes governing each man's action.

The responsible petty officer sets the example he wishes others to follow, doing the right thing in carrying out each assignment, including (and especially so) when no one is watching. Undiluted professionalism means that there is no room for ethical lapses or occasional breaches of integrity. The worker who even once shortcuts established procedures, does not follow maintenance manual instructions, sacrifices quality for speed, or performs any other action which produce a negative judgement towards him lacks the professional integrity demanded in the Machinist's Mate rate. The supervisor who condones such action is equally guilty of a less than professional attitude and the results that such actions could cause.

There is no substitute for thorough knowledge of your ship, your job, and the procedures associated therewith. Correct maintenance procedures and thorough quality assurance will almost always produce professional results. Ship safety demands pure, undiluted professionalism from all personnel involved in maintenance.

MAINTENANCE AND REPAIR RESPONSIBILITIES

To fulfill your administrative and supervisory responsibilities in connection with maintenance and repair, you must have the ability to plan ahead. During an average workday, occasions will arise when personnel have to leave their working spaces for one reason or another, thereby delaying the completion of the scheduled work. Some delays can be anticipated; some cannot. Among the delays which can be anticipated are training lectures, immunization schedules, rating examinations, meals, and watches or other military duties.

Before making personnel work assignments, the supervisor should determine what delays can be anticipated. It may be possible to arrange assignments so that work interruption is held to a minimum. When estimating the completion time of a maintenance task, the supervisor should allow for these predictable delays.

Some engineroom maintenance and repair work just won't fit into a schedule but must be done whenever the opportunity arises. So, in addition to having the ability to plan, you must have a certain amount of flexibility so that you can alter your plans to fit the existing circumstances. A few administrative and supervisory considerations that apply particularly to maintenance and repair are noted in the following sections.

Materials and Repair Parts

The responsibility for maintaining adequate stocks of repair parts and repair materials belongs at least as much to you as it does to the supply department. The duties of the supply officer are to procure, receive, stow, issue, and account for most types of stores required for the support of the ship. However, the supply officer is not the prime user of repair parts and repair materials; the initiative for maintaining adequate stocks of repair materials, parts, and equipment must come from the personnel who are going to use such items.

Basic information on supply matters is not included here because it is given in *Military Requirements for PO 3 & 2*, NAVEDTRA 10056-C, and *Military Requirements for PO 1 & C*, NAVEDTRA 10057-C. However, a few points are noted here concerning the identification of repair parts and materials. Identification is not usually any great problem when you are dealing with familiar equipment on your own ship; but it may present problems when you are doing repair work for other ships, as you would be if assigned to the machine shop on a repair ship or tender.

The materials and repair parts to be used are specified for many repair jobs but not for all. When materials or parts are not identified in the instructions accompanying a job, you will have to do some research to find out just what material or part should be used. When you must make the decision yourself, select materials on the basis of the service conditions they must withstand. Operating pressure and operating temperature are primary considerations in selecting materials and parts for most engineroom repair work. Special considerations may also apply; for example, high temperature steam piping must be made of material that has the property of creep resistance.

When materials and repair parts are not specified in the instructions accompanying a job, this does not always mean that you are free to use your own judgment. Instead, it may merely mean that you are expected to know where to look for information on the type of material or repair parts to be used. The shipboard sources of information that will be most helpful to you in identifying of selecting materials and repair parts include (1) nameplates on the equipment, (2) manufacturer's technical manuals and catalogs, (3) stock cards maintained by the supply officer, (4) ships' plans, blueprints, and other drawings, and (5) allowance lists.

NAMEPLATES on equipment supply information regarding the characteristics of the equipment and are therefore a useful source of information concerning the equipment itself. Nameplate data seldom, if ever, includes the exact materials required for repairs; however, the information given on the characteristics of the equipment and on pressure and temperature limitations may provide useful clues for the selection of materials.

MANUFACTURERS' TECHNICAL MANUALS are furnished with all machinery and equipment aboard ship. Materials and repair parts are sometimes described in the text of these technical manuals; more commonly, however, details of materials and parts are given on the drawings. Manufacturers' catalogs of repair parts are also furnished with some shipboard equipment; when available, these catalogs are a valuable source of information on repair parts and materials.

The set of STOCK CARDS that is maintained by the supply officer is often a useful source of information on repair materials and repair parts. One stock card is maintained for each type of machinery repair part carried on board.

SHIPS' PLANS, BLUEPRINTS, and other drawings available on board ship are excellent sources of information on materials and parts to be used in making various kinds of repairs. Many of these plans and blueprints are furnished in the regular large sizes; but microfilm is being used increasingly for these drawings. Information obtained from plans, blueprints, and other drawings should always be checked against the information given on the ship's COORDINATED SHIPBOARD ALLOWANCE LIST (COSAL), to be sure that any changes made since the original installation have been noted on the drawings.

The COSAL for each ship is a basic source of information on repair parts and materials. The COSAL gives nomenclature and Federal Stock Numbers for all hull, machinery, electrical, ordnance, and electronics materials.

To request materials and repair parts from the supply department aboard ship, you must fill out and submit a NAVSUP Form 1250, Single Line Item Consumption/Management Document. If the item is not stocked aboard ship, the supply department will requisition the material from a supply activity, using the identifying information that you have given on the NAVSUP Form 1250.

Whenever you find it necessary to request materials or repair parts, remember two things:

1. If at all possible, find the correct Federal Stock Number for each item requested. All materials now in the supply system have been assigned Federal Stock Numbers, and you should be able to locate them by using the COSAL and the other sources of information available to you.
2. Work informally with the supply department personnel who are actually responsible for identifying and requisitioning material. You have the technical knowledge, and you know what you need. If you cannot find the correct stock number, however, your problem is to give enough standard identification information so that supply personnel on board ship or ashore can identify the item you want. Experienced supply personnel are familiar with identification publications and can help you to locate the correct stock numbers and other important identifying information.

Repairable Items

As equipments and systems in the Navy grow more complex and more difficult to maintain at operating level, increasing use is being made of replacement equipments, components or modules. These recoverable items or repairables, as they are called, are components of a system or equipment (e.g., electronic control box, oxygen generator) or end items such as a governor or portable pump which are replaced periodically or upon failure and can be economically restored to a serviceable condition. When the technician removes the failed repairable, he draws a serviceable one to replace it and turns the failed item in for repair. This returned material, through repair and rework, then becomes an additional source of supply to the Inventory Manager. The decision that an item will be managed as a repairable is made by the Materials Systems Commander or Project Manager concerned during the provisioning process.

Most repairables by their nature are essential to the performance of the mission of the system of which they are a part. In order to maintain an effective turn around time, a higher degree of control is required to manage this material, not only on the part of the Inventory Manager but also by the Fleet Commanders-in-Chief, Fleet units, and commercial and Material Systems Command repair facilities. In addition, repairables are normally expensive and constitute a high inventory investment.

Scheduling Work

Careful planning is required to keep up with all engineroom maintenance and repair work. Some of the factors that may be helpful in scheduling maintenance and repair work are:

1. Size up each job before you let anyone start working on it. Checking the applicable Maintenance Requirement Cards so that you will know exactly what needs to be done. Also, check all applicable drawings.
2. Check on materials before you start. Be sure that all required materials are available before your men start working on any job. Do not overlook small items—nuts, bolts, washers, packing and gasket materials, tools, measuring devices, and so forth. A good deal of labor can be saved by the simple process of checking on the availabiltiy of materials before a job is actually started. An inoperable piece of machinery may be useless; but it can become a positive nuisance and a safety hazard, as well as useless, if it is spread around the engineroom in bits and pieces while you wait for the arrival of repair parts or materials.
3. Check on the priority of the job and of all other work that needs to be done before scheduling any job.
4. When assigning work, give careful consideration to the capabilities and experience of your men. As a rule, the more complicated jobs should be given to the more skilled and more experienced men. When possible, however, the less experienced men should be given difficult work to do under supervision so that they may acquire skill in such jobs.

When assigning work, be sure that the man who is going to do a job is given as much information as necessary. An experienced man may need only a drawing and a general statement concerning the nature of the job. A less experienced man is likely to require additional instructions and, as a rule, closer supervision.

5. Keep track of the work as it is being done. In particular, check to be sure that proper materials and parts are being used, that the job is properly laid out or set up, that all tools and equipment are being used correctly, and that all safety precautions are being observed.

6. After a job has been completed, make a careful inspection to be sure that everything has been done correctly and that all final details have been taken care of. Check to be sure that any necessary records or reports have been prepared. Remember that job inspections can serve at least two very important purposes: first, to make sure that the work has been properly performed; and second, to increase the skills and knowledge of the person who has done the work. Do not overlook the training aspects of a job inspection. When your inspection of a completed job reveals and defects or flaws, be sure the man understands what is wrong, why it is wrong, and how to avoid similar mistakes in the future.

Estimating Work

You will often be required to estimate the amount of time, the number of men, and the amount of material that will be required for repair jobs. Actually, you are making some kind of estimate every time you plan and start a repair job, as you consider such questions as: How long will it take? Who can best do the job? How many men will be needed? Are all necessary materials available?

However, there is one important difference between the estimates you make for your own use and those that you make when your division officer asks for estimates. When you give an estimate to someone in authority over you, you cannot tell how far up the line this information will go. It is possible that an estimate you give to your division officer could utimately affect the operational schedule of the ship; it is essential, therefore, that such estimates be as accurate as you can possibly make them.

Many of the factors that apply to the scheduling of all maintenance and repair work apply also to estimating the time that will be required for a particular repair job. You cannot make a reasonable estimate until you have sized up the job, checked on the availablity of materials, checked on the availability of skilled personnel, and checked on the priority of the various jobs for which you are responsible. In order to make an accurate estimate of the time required to complete a specific repair job, you must also consider (1) what part of the work must be done by other shops, and (2) what kinds of interruptions and delays may occur. These factors are also important in the routine scheduling of maintenance and repair work; but they are particularly important when you are making estimates of time that may affect the operational schedule of the ship.

If part of the job must be done by other shops, you must consider not only the time actually required by these other shops but also the time that may be lost if one of them holds up your work. Each shop should make a separate estimate, and the estimates should be combined in order to obtain the final estimate. Do NOT attempt to estimate the time that will be required by other personnel. Attempting to estimate what someone else can do is risky because you can't possibly have enough information to make an accurate estimate.

Estimating the number of men who will be required for a certain repair job is, obviously, closely related to estimating time. You will have to consider not only the nature of the job and the number of men available but also the number of men who can work EFFECTIVELY on a job or on part of the job at the same time. On many jobs, there is a sort of natural limit to the number of men who can work effectively at any one time. On a job of this kind, doubling the number of men will not cut the time in half; instead, it will merely result in confusion and aimless milling around.

Perhaps the best way to estimate the time and the number of men that will be required is to divide the total job into the various phases or steps that will have to be done, and then estimate the time and the men required for each step.

Estimating the materials required for a repair job is often more difficult than estimating the time and labor required for the job. Although your own past experience will be your best guide for this kind of estimating, a few general considerations should be noted:

1. Keep accurate records of all materials and tools used in any major repair job. These records serve two purposes: first, they provide a means of accounting for materials used; and second, they provide a guide for estimating materials that will be required for similar jobs in the future.

2. Before starting any repair job, plan the job carefully and in detail. Make full use of manufacturers' technical manuals, blueprints, drawings, and any other available information and try to find out in advance all the tools and materials that will be required for the accomplishment of each step of the job.

3. Make a reasonable allowance for waste when calculating the amount of material you will need.

TRAINING

By the time a man has reached the MM2 or MM1 level, he has acquired a great many practical skills and a large amount of theoretical knowledge. Among other things, he has learned a good deal about–

Construction details, operating principles, and operating characteristics of all types of naval propulsion plants and associated engineroom auxiliary machinery; propulsion plant layout and piping system arrangement; principles of steam engineering, including theory of combustion, theory of energy transformations, and factors governing engineroom and fireroom efficiency; nature and theory of engineroom operations; operational troubleshooting; engineering casualty control; engineroom maintenance and repair; characteristics of metals and alloys; tests and inspections of main engines; characteristics and tests of lube oil; and records, reports, and other administrative requirements.

As you well know, this is only a partial list of the skills and knowledges you must have in order to qualify as an expert Machinist's Mate. But even a very wide range of abilities and an extensive theoretical knowledge will not, in themselves, guarantee your success as an instructor. You must be technically competent before you can teach others; but your technical competence must be supplemented by the ability to organize information, to present it effectively, and to arouse and keep the interest of your students.

You will find excellent general information on how to plan, carry out, and evaluate and instructional program in the *Manual of Navy Instructors*, NAVEDTRA 16103-C; in *Military Requirements for PO 3 & 2*, NAVEDTRA 10056-C; and in *Military Requirements for Petty Officers 1 & C*, NAVEDTRA 10057-C. The present discussion does not include basic information of the type given in these references; instead, it deals with some of the difficulties peculiar to the training of engineroom personnel and some of the ways in which you can overcome or minimize these difficulties.

Training of personnel is a necessary function and one of the most important responsibilities of senior petty officers. A Chief Machinist's Mate and to some extent a First Class, will have regular and continuing responsibilities for the training of others. Even if a supervisor is fortunate enough to have a group of men who are highly skilled and well trained, he will find that training is still necessary. For example, the training of strikers and lower rated men for advancement examinations is a continuing, never-ending process. The Navy rotation policy being what it is, the best men will eventually be transferred and replacements will, in most instan es, require training before they can be relied on to take their places as effective members of the organization. These and similar problems require the division supervisor to be well versed in the several aspects of training–able to set up as well as conduct an effective training program for assigned personnel.

ORGANIZING A TRAINING PROGRAM

Organizing a training program involves such considerations as planning lessons and job plans, selecting and qualifying instructors, making arrangements for classroom space, phasing the training program with the scheduled workload, procuring visual and other training aids, and determining teaching methods for each lesson or lesson series.

The subject matter areas to be included in the training program are (1) material relating to maintenance of equipment supported, (2) general material required by the men for advancement examinations, and (3) material relating to safety. In most cases lessons will fall under more than one of the subject areas.

Once it has been determined what publications will adequately cover the subject areas, the material must be divided into lessons, and lesson guides prepared.

The lectures are numbered to provide a means of recording each man's progress within his individual training folder. A training syllabus sheet should be prepared for each man in the division to provide a handy index to the state of training of the division personnel as a whole.

Whether the supervisor teaches the lessons himself or assigns other petty officers to conduct them depends on the state of training of his first and second class petty officers. A requirement for advancement for third class petty officers and nonrated personnel is satisfactory completion of the nonresident career course based on *Military Requirements for Petty Officer 3 & 2,* NAVEDTRA 10056 (Series). This course sets forth some of the basic principles of training in general and teaching in particular.

An advancement requirement for second and first class petty officers is satisfactory completion of the nonresident career course based on *Military Requirements for Petty Officer 1 & C,* NAVEDTRA 10057 (Series). The latter course expands and amplifies training theory and introduces job analyses, training aids, and testing. For the first time in his career the prospective First Class Machinist's Mate is required to demonstrate his ability to formally teach, use various training aids, and prepare and administer written tests. In order to demonstrate correct instructional techniques, the supervisor may elect to teach certain lessons himself or assign them to a competent instructor for the same purpose. Later he may assign less proficient petty officers as instructors so that they may acquire the experience necessary for completing their practical factors for advancement.

If at all possible, training sessions should be conducted at the same time of day and on a regular schedule. Factors to consider when scheduling lessons are usual meal hours, watches, availability of classroom, and work schedule.

Some lessons are better suited for one type of instructional technique than others. The type of presentation for each lesson should be planned in advance. This will also facilitate the rotation of the lessons among the petty officers who require experience in teaching.

The effectivity of Machinist's Mate technical training is greatly enhanced by the use of training aids. The supervisor should always be on the alert for scrap material that can be converted to training aids with minimum expense. He must be aware of the existence of applicable training films and, if they are available, schedule them for showing in conjunction with specific lessons.

When planning a training program, the supervisor should decide where the classroom sessions should be conducted. The space selected should preferably be in a quiet area or at least one with a minimum of noisy distractions. The area should be large enough to accommodate the expected student load and be well lighted. Adequate ventilation will help keep the men awake and interested in the presentation. Convenience is another factor in the selection of classroom space. Some of the desirable space characteristics may, on occasion, have to be sacrificed in order to find a classroom nearer to the working area.

TRAINING PROCEDURES

Training procedures are of two general types—formal and informal.

Formal training is conducted in the classroom through lectures, supplemented by required reading and implemented by the use of all available visual aids. A schedule of training is prepared and published periodically by the training officer. It lists the time of the training, the location of the classroom, the names of the men who are to attend, the subject of the lesson, and the name of the instructor.

Lesson guides are prepared by the division officer and chief or first class petty officers who are qualified to do so. The lesson guides should contain the title, objective(s), time to be consumed in presenting the lesson, list of instructional aids, list of references, outline for presentation, and a summary of the lesson.

When a petty officer has been assigned to instruct a given lesson, it is his responsibility to procure a copy of the lesson guide and from it prepare his lesson plan. Lesson plans are prepared by each individual instructor based on the lesson guide; and though they may differ from instructor to instructor, they must adequately cover the subject.

Informal training is the practical instruction of men in the performance of maintenance tasks by means of demonstration and imitation under personal supervision in the engineroom or shop. Nearly every maintenance task that is undertaken presents an opportunity for on-the-job training. The experienced men of the division are utilized as fully as possible in demonstrating and imparting their skills to the less experienced.

Under this system, the trainee has the opportunity to actually do the job under the supervision of an experienced petty officer. The only equipment necessary is the job itself. It is neccessary, of course, that the instructor have an interest in the job and the skill to do it well. The striker or trainee will learn by seeing the job performed, and he will gain experience by having a chance to participate in the accomplishment of the job.

The nature of informal training makes regular scheduling impracticable. Actually, it is done at every opportunity. A training syllabus is prepared under the guidance of the training officer, with content and scope corresponding with practical factor requirements of the personnel. On-the-job training is reported by the leading petty officer instructors and supervisors to the division officers on the training syllabus at regular intervals so that a close watch may be made on individual progress. The records are for review by higher authority and will point out the need for training in special areas as well as certain practical factors. The degree of success in on-the-job training depends on the degree of recognition by each individual of his responsibility to his outfit to impart his skill and knowledge to the man who is trying to learn.

TRAINING DOCUMENTATION AND RECORDKEEPING

The individual Training Syllabus Sheet pro-[illegible]s a record of formal lectures attended by the division. A report of practical training (OJT) should be made to the division officer at regular intervals. This will indicate to the division officer that a man has fulfilled a satisfactory level of skill to justify completing of the various items listed on the individual's practical factors for advancement sheet. The formal training syllabus record and the record of practical training will indicate that required training has been completed in all areas or that a need for special training exists and further certifies when the individual may be considered qualified for advancement.

PERSONNEL QUALIFICATION STANDARDS

Personnel Qualification Standards (PQS) are presently being developed to provide guidelines in preparing for advancement and qualification to operate specific equipment and systems. They are designed to support the advancement requirements as stated in the *"Quals" Manual.*

The "Quals" and Record of Practical Factors are stated in broad terms. Each PQS is much more specific in its questions that lead to qualification. It provides an analysis of specific equipment and duties, assignments, or responsibilities which an individual or group of individuals (within the same rating) may be called upon to carry out. In other words, each PQS provides an analysis of the complete knowledge and skills required of that rating tied to a specific engineering system and/or individual systems of components.

Each qualification standard has four main subdivisions in addition to an introduction and a glossary of PQS terms. They are as follows:

100 Series–Theory
200 Series–Systems
300 Series–Watchstations (duties, assignments, or responsibilities).
400 Series–Qualification cards

The introduction explains the complete use of the qualification standard in terms of what it will mean to the user as well as how to use it.

The Theory (100 Series) section specifies the theory background required as a prerequisite to the commencement of study in the specific equipment or system for which the PQS was written. These fundamentals are normally taught in the formal schools (Preparatory, Fundamentals, and Class A) phase of an individual's training. However, if the individual has not been to school, the requirements are outlined and referenced to provide guidelines for a self-study program.

The Systems (200 Series) section breaks down the equipment or systems being studied into functional sections. PQS items are essentially questions asked in clear, concise statement (question) form and arranged in a standard format. The answers to the questions must be extracted from the various maintenance manuals covering the equipment or systems for which the PQS was written. This section asks the user to explain the function of the system, to draw a simplified version of the system from memory, and to use this drawn schematic or the schematic provided in the maintenance manual while studying the system or equipment. Emphasis is given to such areas as maintenance management procedures, components, component parts, principles of operation, system interrelations, numerical values considered necessary to operation and maintenance, and safety precautions.

The Watchstation (300 series) section includes questions regarding the procedures the individual must know to operate and maintain the equipment or system. A study of the items in the 200 series section provides the individual with the required information concerning what the system or equipment does, how it does it, and other pertinent aspects of operation. In the 300 series section, the questions advance the qualification process by requiring answers or demonstrations of ability to put this knowledge to use or to cope with maintaining the system or equipment. Areas covered include normal operation; abnormal or emergency operation; emergency procedures which could limit damage and/or casualties associated with a particular operation; operations that occur too infrequently to be considered mandatory performance items; and maintenance procedures/instructions such as checks, tests, repair, replacement, etc.

The 400 series section consists of the qualification cards. These cards are the accounting documents utilized to record the individual's satisfactory completion of items necessary for becoming qualified in duties assigned. Where the individual starts in completing a standard will depend on his assignment within an activity. The complete PQS is given to the individual being qualified so that he can utilize it at every opportunity to become fully qualified in all areas of his rating and the equipment or system for which the PQS was written. Upon transfer to a different activity, each individual must requalify. The answers to the questions asked in the qualification standards may be given orally or in writing to the supervisor, the branch or division officer, and maintenance officer as required to certify proper qualification. The completion of part or all of the PQS provides a basis for the supervising petty officer and officer to certify completion of Practical Factors for Advancement.

ENGINEERING OPERATIONAL SEQUENCING SYSTEM

The many varied types of engineering plants existent in today's modern Navy require an ever increasing range and depth of operational knowledge by engineering personnel at all levels of shipboard operations. The Engineering Operational Sequencing System (EOSS) provides each of these levels with the required information to enable the engineering plant to respond to any demands placed upon it which are within its design capability.

The Engineering Operational Sequencing System is a set of systematic and detailed written procedures, utilizing charts, instructions and diagrams which provide the information required for the operation and casualty control functions of a specific shipboard propulsion plant.

The system will improve the operational readiness of the ship's engineering plant by increasing its operational efficiency, providing better engineering plant control, reducing operational casualties and extending equipment life. The advantages are accomplished by first defining the levels of control and operation within the engineering plant and then providing each supervisor and operator with the information he needs to know, in words he can understand, at the watch station. The EOSS is composed of three basic parts:

1. The USERS GUIDE, installed with each system, is a booklet which explains the EOSS package and how it is used to the ship's best advantage. It contains samples of the various documents and explains how they are used. Recommendations are also included for introduction of the EOSS system and methods of training the ship's personnel in utilization of these procedures installed aboard ship.

2. The ENGINEERING OPERATIONAL PROCEDURES contain all the information necessary for the proper operation of a ship's engineering plant as well as aids in scheduling, controlling and directing plant evolutions from receiving shore service to underway and back down.

3. The ENGINEERING OPERATIONAL CASUALTY CONTROL contains information relative to recognizing certain symptoms of a casualty and their probable causes and effects. It also contains information providing preventive action that may be taken to preclude a casualty as well as procedures for controlling single source and multiple (cascade effect) casualties.

CHAPTER 12

PROPULSION PLANT EFFICIENCY

The military value of a naval ship depends to a large extent on its cruising radius, which in turn depends upon the efficiency with which a propulsion plant is operated. Economical operation involves making fuel, lubricating oil, boiler feed water, potable water, and consumable supplies last as long as possible. A ship is not ready for wartime steaming unless the engineering department can and does operate reliably and efficiently. It is, therefore, important that engineering personnel maintain propulsion equipment in a reliable condition and that the equipment be operated at maximum efficiency.

The primary purpose of the peacetime Navy is to train and prepare personnel for wartime conditions. However, in peacetime, maximum economy must be practiced to keep operating and maintenance costs at a minimum.

The operation of an engineering plant cannot be considered reliable when machinery casualties occur frequently. Some of the more common causes of machinery casualties are:

1. Changing the setup of the plant at high speeds.
2. Radical maneuvering of the ship.
3. Inexperienced or improperly trained personnel.
4. Lack of inspections or improper inspections.
5. Inattentive watchstanding.
6. Poor supervision.
7. Failure to establish responsibility.
8. Inadequate repairs, maintenance, and preventive maintenance.

Accurate knowledge and continuous effort are required to keep propulsion plants operating reliably and efficiently. It is necessary for the personnel concerned to be familiar with the chapters of *NAVSHIPS Technical Manual* which deal with main propulsion plants and associated auxiliary equipment. It is also necessary for personnel to have an accurate knowledge of the appropriate manufacturer's technical manuals, official publications, and directives on operational procedures and material upkeep.

When a ship is underway, the MMC or MM1 will normally stand watch as the petty officer in charge of an engineroom. The MM2 must be capable of operating any specific unit of machinery or piping system. As the senior petty officer of the watch, the MMC or MM1 must be capable of supervising all the operations of the propulsion and auxiliary machinery and piping systems that are applicable to any watch station to which he may be assigned. The senior petty officer must also be capable of supervising the overall operation of the entire propulsion plant, which includes the other engineroom(s) and the firerooms.

On ships having more than one main propulsion plant, the associated engineroom and fireroom are usually operated together as one unit. On some auxiliary ships this one unit constitutes the entire propulsion plant; on combatant ships, this unit may be one of two or four separate propulsion plants. The physical characteristics of compartments and bulkheads, or the location and arrangement of machinery and equipment, do not change the operating principles of a main propulsion plant. On older ships, it was necessary to operate two separate spaces as one basic unit; however, on most new large combatant ships, NAVSEA has changed this arrangement. The present machinery arrangement has the basic propulsion plant, consisting of boilers, main engines, turbogenerators, and auxiliary machinery of the associated engineroom and fireroom, in one compartment. This compartment is called a main machinery room.

In operating the associated engineroom and fireroom as one complete propulsion plant, maximum reliability and efficiency cannot be obtained unless there is cooperation, understanding, and teamwork between engineroom and fireroom personnel. A great deal depends upon the knowledge and supervisory ability of the senior watchstander in each main machinery space. The MM in charge of the engineroom should have a practical knowledge of fireroom operation, of safety precautions, and of the casualties that may occur during operation of the engineering plant.

On destroyers, most auxiliary ships, and most small ships, the MM in charge of the control engineroom will also be in charge of the entire engineering plant and will assume the duties of the officer of the watch. When the MM assumes the officer of the watch duties, he must have a thorough understanding of the routine procedures and regulations concerning the entire engineering department.

The MM in charge of a watch must see that the officer of the deck (OOD) and the engineer officer are immediately informed of all important facts concerning the operation of the main engines. The MM of the watch is responsible for reporting to the engineer officer and the OOD such items as casualties to machinery, the number of boilers available, the number of generators available, and the maximum speed of which the ship is capable. He must also report such operations as placing a major unit of machinery in or out of commission, starting a generator, lighting fires under a boiler, and securing a generator or boiler. The MM of the watch must also be capable of carrying out appropriate engineering casualty control procedures for the overall operation of the propulsion plant. Each individual casualty will be handled by the personnel on watch; the Machinist's Mate in charge of the watch will take such steps as may be necessary to minimize the effect of the casualty on the overall operation of the plant.

ENGINEERING PERFORMANCE

During peacetime, the objective of engineering department training in the fleet is to create and maintain readiness to deliver the designed performance of the engineering plant at all times. Such readiness includes the ability to operate free of breakdowns, to control engineering damage, to make prompt and effective emergency repairs, and to operate the engineering plant safely and economically. Administrative instructions are provided each ship for the purpose of furnishing a general and uniform guide by which type commanders or their subordinates may estimate or evaluate the engineering performance and readiness of the ships assigned to their command.

ENGINEERING RELIABILITY

A ship must be capable of performing any duty for which it was designed. A ship is considered reliable when it meets all scheduled operations and is in a position to accept unscheduled tasks. In order to do this, the ship's machinery must be kept in good condition so that the various units will operate as designed. Some of the steps to promote reliability are:

1. A good preventive maintenance program must be carried out at all times. This involves regular tests, inspections, and repairs.
2. Machinery and piping systems must be operated in accordance with good engineering practices. Operating instructions and safety precautions should be posted for each unit of machinery.
3. Supervisory personnel must have a thorough knowledge of the ship's machinery and piping systems. Information on construction, operation, maintenance, and repair of machinery can be obtained from the manufacturer's technical manuals and blueprints.
4. A good engineering department administrative organization will ensure proper assignment of duties and responsibilities and proper training and supervision of personnel. The MMC and MM1 will have administrative and supervisory duties. As a supervisor, the MMC or MM1 must see that all pertinent instructions and procedures are carried out in regard to the proper operation, maintenance, and repair of machinery.

5. Personnel must be thoroughly trained. This can be best accomplished by a combination of methods. An effective method of training is to have the students learn by doing; a good example of this is watchstanding. Another method of training is carrying out regularly scheduled and well planned instruction periods. These instruction periods are not limited to classroom instruction—they may be conducted by holding engineering casualty control drills while under way.

ENGINEERING PLANT ECONOMY

In order to obtain economy, the engineering plant, while meeting prescribed requirements, must be operated so as to use a minimum amount of fuel. The FUEL PERFORMANCE RATIOS are good overall indications of the condition of the engineering plant and the efficiency of the operating personnel. The fuel performance ratio is the ratio of the amount of fuel oil used as compared to the amount of fuel oil allowed for a certain speed or steaming condition. The fuel performance ratio, which is reported on the Monthly Summary, is a general indication of the ship's readiness to operate economically and within established standards. In determining the economy of a ship's engineering plant, the same consideration is given to the amount of water used on board ship. Water consumption is computed in (1) gallons of makeup feed per engine mile, (2) gallons of makeup feed per hour at anchor, and (3) gallons of potable water per man per day

The increase or decrease in a ship's fuel economy depends largely on the operation of each unit of machinery; economical operation further depends on personnel understanding the function of each unit and knowing how units are used in combination with other units and with the plant as a whole

Good engineering practices and safe operation of the plant should never be violated in the interest of economy—furthermore, factors affecting the health and comfort of the crew should meet the standards set by the Navy.

Indoctrination of the ship's crew in methods of conserving water is of the utmost importance, and should be given constant consideration.

Economy Versus Safety

Aboard naval ships, economy measures cannot be carried to extremes, because there are several safety factors that must be considered. Unless proper safety precautions are taken, reliability may be sacrificed; and in the operation of naval ships, reliability is one of the more important factors. In operating an engineering plant as economically as possible, safety factors and good engineering practice must not be overlooked.

Notes on Efficient Operation

There are several factors that, if given proper consideration, will promote efficient and economical operation of the engineering plant. Some of these factors are: (1) maintaining the designed steam pressure, (2) proper acceleration of the main engines, (3) maintaining designed condenser vacuum, (4) guarding against excessive recirculation of condensate, (5) maintenance of proper insulation and lagging, (6) keeping the consumption of feed water and potable water within reasonable limits, and (7) conserving electrical power, (8) using the correct number of boilers for best efficiency at the required load levels, and (9) maintaining minimum excess combustion air to the boilers.

MAINTAINING A CONSTANT STEAM PRESSURE is important to the overall efficiency of the engineering plant. Wide or frequent fluctuations in the steam pressure or degree of superheat above or below that for which the machinery is designed will result in a considerable loss of economy. Excessively high temperatures will result in severe damage to superheaters, piping, and machinery.

PROPER ACCELERATION AND DECELERATION OF THE MAIN ENGINES is an important factor in the economical operation of the engineering plant. A fast acceleration will not only interfere with the safe operation of the boilers but will also result in a large waste of fuel oil. The Machinist's Mate in charge of an engineroom watch, or standing throttle watch, can contribute a great deal to the economical and safe operation of the boilers.

A HIGH CONDENSER VACUUM can be obtained only by the proper operation and proper maintenance of the condenser. A low exhaust pressure (high vacuum) is an important factor in obtaining maximum engineering efficiency. Steam exhausting into a low pressure area has a greater range of expansion and therefore is capable of accomplishing more useful work. The total available energy in the steam is much higher per pound of pressure difference in the lower range of pressures than in the upper range. This is the most important reason why the condenser vacuum should be maintained as high as possible.

EXCESSIVE RECIRCULATION OF CONDENSATE should be avoided as it cools the condensate, which then has to be reheated as it enters the deaerating feed tank. This reheating process causes an excessive amount of steam to be used to maintain the proper temperature in the deaerating feed tank. The principle of operation of the thermostatically controlled recirculating valve is discussed in *Machinist's Mate 3 and 2* and in *NAVSHIPS Technical Manual*. The use and operation of this valve should be thoroughly understood by operating personnel.

MAINTENANCE OF PROPER INSULATION AND LAGGING not only increases the overall economy of the engineering plant but also is a safety measure and increases the comfort of personnel. In every power plant there is a heat loss as heat flows from heated surfaces, such as piping and machinery, to the surrounding air and cooler objects. This heat loss can be kept to a minimum by proper insulation.

While increasing the economy of the plant, insulation also reduces the quantity of air necessary for ventilating and cooling the space. Proper insulation also reduces the danger of personnel receiving burns from contact with the hot parts of the piping, valves, and machinery. Good insulation, elimination of steam leaks, and a clean ventilation system contribute to good economy and to the comfort and safety of personnel.

CONSERVATION OF FEED WATER AND POTABLE WATER has a direct bearing on the overall efficiency and economy of the ship. Feed water and potable water consumption rates are entered on the Monthly Summary. Type commanders use these consumption rates as a factor for judging the efficiency of ships operating under their command. Ships having excessive feed water consumption rates should take immediate steps to eliminate all steam and water leaks which contribute to the uneconomical operation of the plant. Improving feed water consumption rates will also improve the fuel oil performance ratio.

The consumption of potable water by the ship's crew bears a direct relationship to the efficient operation of the engineering plant; the greater the amount of fresh water distilled, the greater the amount of steam used. Conservation of fresh water requires the close cooperation of all personnel aboard ship, since large amounts may be wasted by improper use of the laundry, scullery, galley, and showers.

FAILURE TO CONSERVE ELECTRICAL POWER is a very common source of waste aboard ship. Lights are frequently left on when not needed, and bulbs of greater wattage than required are often used.

If the ship's ventilation system is improperly operated or improperly maintained, the result is a waste of electrical power. Vent sets are often operated on high speed when low speed operation would provide adequate ventilation and cooling. Dirty and partially clogged ventilation screens, heaters, cooling units, and ducts will result in inefficient operation and power loss.

In checking the operation of the engineering plant for efficiency, the proper operation and maintenance of all units of auxiliary machinery must be considered. Economical operation of the distilling plants and of the air compressors will contribute a great deal to the overall efficiency of the plant. Because of the large number and various types of pumps aboard ship, their operation and maintenance are important factors. Units of machinery that operate continuously (or most of the time) must be given careful attention with respect to efficient operation and maintenance.

The following are specific recommendations for the efficient operation of engineering plants:

1. Use the minimum number of forced draft blowers. It is more economical to run one blower at or near its designed speed than to run two blowers at a lower speed.

2. Do not operate with excessive feed water pressures. Excessive pressure results in a wasteful amount of steam being used to drive the pump.

3 Maintain proper fuel oil temperature. Do not operate more fuel oil heater units than are necessary for proper heating. Overheating fuel oil wastes steam and overheated fuel oil fouls the heaters.

4. Maintain superheated steam temperature as close to the designed temperature as operating conditions permit.

5. Steam with a light brown haze, whenever permissible, 10 to 15 percent excess air is approximately right for this kind of steaming. If smokeless steaming is required, slightly more than 10 to 15 percent excess air will be necessary.

6. Boiler casings should always be tight. Leaky casings result in excessive fuel consumption because additional steam is required to increase blower capacity and heat is conducted away from the boiler by leaking air.

7. High feed water consumption indicates an uneconomical plant. No feed water leak is too small to be neglected.

8. Keep the steam pressure temperature as steady as is feasible at all times.

9. Throttlemen must carefully follow the acceleration and deceleration table posted on the throttle board.

10. Check the condensing system frequently for proper operation and tightness.

11. Check the operation of the deaerating feed tank frequently.

12. Keep all drain valves, drain lines, and steam traps in good working condition.

13. All orifice plates in piping systems should be checked for good material condition, proper size, and proper operation.

14. Keep the steam pressure to the air ejectors steady and at the designed pressure.

15. Keep the thermostatically controlled recirculating valve in good working condition and operate it properly.

16. Keep the auxiliary exhaust pressure at the designated value by maintaining the automatic dumping valves in good working condition.

17. Follow the proper procedures in taking on makeup feed.

18. Maintain all insulation and lagging in good condition.

19. Keep the bilges dry. Water in the bilges will add to the humidity of the air, necessitating more ventilation, and causing bilge piping to corrode.

20. Keep ventilation systems clean at all times.

21. Ventilation motors should be run on low speed unless high speeds are necessary.

22. Whenever the ship's electrical load will permit, one generator, rather than two, should be operated. It is more economical to operate one generator at near full load than to operate two generators at light loads.

23. Maintain proper lubricating oil temperatures. Cold lube oil can be an indirect cause of excess fuel oil consumption and improper bearing lubrication.

24. Use the proper number of boilers for best efficiency at the required load condition.

25. Use the proper setup of pumps and other auxiliaries at all times.

26. Keep heat exchangers, such as lube oil coolers, operating efficiently.

27. Keep the condensate depression between 0°F and 2°F.

28. Never sacrifice safety for economy. Personnel may be injured and machinery may be damaged.

Trial Performances

Trial performances, such as full power and economy trials, are conducted to furnish evidence of the ship's engineering plant readiness for peacetime or wartime steaming conditions. By studying the trial performance reports, the type commander and NAVSEA can evaluate the ship's readiness to make required speeds and economy of operation. Information on conducting trial performances will be given in a later chapter of this training manual.

CONTROL OF ENGINEERING CASUALTIES

The ability of engineering department personnel to control engineering damage and make emergency repairs is measured by PERFORMANCE OBSERVED during training exercises and actual emergencies. The first consideration in judging the effectiveness of engineering casualty control lies in evaluating the ability of the ship's force to maintain and repair the ship's machinery and equipment. For complete evaluation, allowances must be made for the age, service, and character of the installed machinery, for time and facilities allotted for maintenance and repair, and for experience and training of engineering personnel.

Another means of judging the readiness and ability of a ship and the ship's crew to perform the operations which might be required of them in time of war is by conducting an OPERATIONAL READINESS INSPECTION (ORI). The ORI consists of conducting battle problems and other operational exercises which involve all divisions aboard ship. The results of the engineering casualty control exercises greatly reflect the condition of the machinery and the effectiveness of the personnel. During such an exercise, too much dependence should not be placed on a few key men. All men should be trained so that smooth teamwork and reliable performance may be obtained.

Careful and continuous efforts by the MM1 and MMC must be carried out to train men on steaming watch. In peacetime, almost all of the engineering casualties occur during a steaming watch, at which time the key men may not be present. These casualties must be handled by the men on watch at the time when they occur. The senior watchstanders should check the training of their watchstanders and have a thorough knowledge of both their ability to stand watch and to handle casualties. The senior watchstanders should take all practical steps to instruct and train men on watch.

GETTING READY TO GET UNDERWAY

Getting a ship underway, especially a large ship, in a smooth and efficient manner depends to a great extent upon the administrative procedures and organization of the engineering department. Posting the steaming watch, the advance supply of information to the supervisory personnel, dissemination of instructions to watchstanders, the mustering and checking of watchstanders on stations, and warming up the main plant and standing by to get underway, require certain procedures, coordination, and instructions by supervisory personnel.

To prevent misunderstanding and confusion, forms and checkoff lists are used in getting the engineering plant ready to get underway. The purpose of checkoff sheets for warming up or securing a main plant is to provide a convenient and simple procedure for checking the required steps in proper sequence. Check-off sheets will ensure that no important step is overlooked or forgotten.

STEAMING ORDERS

Steaming orders are usually written by the engineer officer or the main propulsion assistant. Steaming orders are necessary, especially on large ships, to supply advance information to supervisory personnel and to enable administrative personnel to make necessary preparations.

Steaming orders list the various units of machinery and the readiness requirements of the engineering department. This form usually includes the major machinery to be used, the lighting-off times, the cutting in of boilers, spinning main engines, the times of warming up and putting ship's service generators on the line, standard speed, the name of the engineering officer of the watch, the name of the leading petty officer of the watch, and any additional information that the engineer officer thinks necessary. The steaming orders are generally written the night before the ship is to get underway and left in a convenient location, such as the log room or central control, for the duty officers and duty petty officers to sign. When a petty officer signs the steaming orders, it means that he has read and understood the orders and therefore is fully responsible for carrying out any and all orders applicable to him. The early posting of such orders is essential in getting a large propulsion plant underway with a minimum of confusion.

On smaller ships, such as destroyers, steaming orders are usually brief and simplified. The first part of the engineroom lighting-off sheet is generally used as the steaming orders. Key personnel, such as the MMC, BTC, and EMC, are notified by the engineer officer or by the assistant engineer officer as to the time the ship will get underway. The duty MMC, who has received all the necessary information and instructions, is responsible for making preparations for getting underway.

WARMING UP THE PROPULSION PLANT

When all watchstanders have been mustered in the engineroom or machinery room, the petty officer in charge of the watch should inform main engine control that his space is manned and ready to light off. The officer of the watch or the senior petty officer in main engine control must check to see that all spaces are manned and ready to warm up the main propulsion plant. The officer of the watch or the petty officer who is assuming the duties of the officer of the watch must also see that all other required reports are made to main engine control.

At the time specified by the steaming orders, the senior watchstander will direct the spaces to start warming up the plant in accordance with the engineer officer's orders. A general checkoff sheet, to be followed in getting the plant ready to get underway, is provided for each ship. Checkoff sheets will differ in accordance with each installation and the orders of the engineer officer. A typical warming up procedure is described in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

Many casualties that have occurred during warming up the plant can be traced directly to lack of cooperation between engineroom and fireroom personnel, misunderstanding of orders, lack of coordination by the senior watchstander, starting or securing machinery without orders, and opening or closing valves without orders to do so.

It is very important to hold the boiler load to a minimum until the main feed pump can be warmed up and is ready to feed the boiler. On ships using an emergency feed pump for feeding the in-port boiler, it is very important to warm up the main feed pump as soon as possible. As additional machinery is started, the load on the emergency feed pump increases. Emergency feed pumps are designed to feed a boiler at low loads only; a main feed pump should take the load as soon as one is warmed up and ready to be put on the line.

Another means of keeping the load on the emergency feed pump to a minimum is to keep the main steam stop bypass valve closed until the main feed pump is feeding the boiler.

When an additional boiler is ready to be brought in on the line, the officer of the watch must carefully coordinate the efforts of the engineroom and fireroom watchstanders to prevent casualties. Putting another boiler into service involves starting additional feed booster pumps, main feed pumps, another deaerating feed tank, and splitting the plant. At this point in the warming up process, a lack of cooperation or a misunderstood order can cause several different kinds of casualties; an empty deaerating feed tank, loss of main feed pressure, or loss of electrical power are but a few of the casualties that have occurred. Split-plant valves should never be opened or closed without orders from the officer of the watch in main engine control, and when such orders are received the valves should be opened (or closed) as soon as possible.

REPORTING READY TO ANSWER BELLS

During the last few minutes before the ship is scheduled to get underway, the officer of the watch has many duties and responsibilities to carry out. He must be certain that the items listed on the steaming orders are carried out or will be carried out in accordance with the engineer officer's orders. He must know that all required machinery has been warmed up properly, put on the line, and is running normally. He must be sure that the required boilers are on the line, that all main steam lines have been properly drained and lined up as specified by the lighting-off sheets, that the required number of ship's service generators are on the line, and that the electrical load is split. He must also be sure that the Electrician's Mate and I. C. Electricians have tested the engine order telegraph, the shaft revolution indicator, the steering engines, and the anchor windlass. He must know that the plant is split, and that all standby machinery has been tested and is ready for use, if needed.

The main engines must be tested before the engineering plant is ready to get underway. On a small ship, such as a destroyer, the engineering officer of the watch will request permission from the OOD to test main engines, usually about 15 minutes before the ship is scheduled to get underway. On a large ship, such as a CVA, this request may be made one hour or more before the scheduled departure time.

When the OOD is certain that the area around the screws is clear of boats, lines, or other objects that may foul the screws, he will grant permission to test the main engines. When this permission has been granted, the engineering officer of the watch must notify all engineering spaces. When all main engines have been tested satisfactorily, the engineering officer of the watch will report to the OOD that the engineering department is ready to get underway.

After the main engines have been tested, and while you are waiting to answer bells, the main engines must be turned by steam. The engines are spun, astern and then ahead, to prevent putting way on the ship. Spinning the engines not only heats the casings but also prevents the rotors from bowing. The interval of time between testing main engines and getting underway may be prolonged by weather, traffic, casualties, or other conditions; during this time the main engines must be turned by steam at least once every 3 to 5 minutes. However, if the getting underway time is unduly delayed, the commanding officer may grant permission to engage and start turning gear to keep the engines turning.

FIREROOM OPERATIONS

In order for an MMC or MM1 to carry out his duties properly, he must possess some knowledge of basic fireroom procedures. This is especially true of those installations where an MMC is in charge of the control engineroom while underway. The efficient and safe operation of the engineering plant depends to a large degree on close cooperation between the engineroom and fireroom personnel. This close cooperation, will in turn, depend on the MM's knowledge of the fireroom and the BT's knowledge of the engineroom. By the time personnel in either space have become first class or chief petty officers, they should have a good knowledge of the entire engineering plant. This does not mean that they should be able to switch watchstanding jobs, but they should have a good understanding of what is occurring on the other side of the bulkhead or, in some ships, on the other side of the space.

Close cooperation of personnel in both spaces is always important, and is especially important when warming up or securing the plant because this is the time when many casualties occur. As additional machinery is started in the fireroom, the engineroom should be notified. In many instances, the fireroom should be notified as machinery is started or secured in the engineroom. It should NEVER be taken for granted that personnel in other spaces know which machinery is in operation.

Most combatant ships have either single-furnace or double-furnace boilers. A number of older ships (chiefly auxiliaries) have header-type boilers. A few ships of recent design are equipped with a new type of boiler called a pressurized-furnace or supercharged boiler. The present discussion is limited to pointing out certain operational differences between double-furnace and single-furnace boilers, since these are the two most commonly used types at the present time.

The double-furnace boiler with controlled superheat is installed on many combatant ships built up to the end of World War II. The operating pressure of this type boiler is approximately 615 psig with a maximum superheater outlet temperature of 850°F. The superheaters of these boilers cannot safely be fired unless there is a safe minimum flow of steam passing through the superheaters.

On large combatant ships, there is usually sufficient steam flow (even when steaming for auxiliary purposes) to maintain fires under the superheater side. However, in most installations, and particularly in destroyers, it is usually necessary to be underway and making about 12 knots before the fires can be lighted under the superheater side of the boiler. When the superheater is operating and the steam flow drops below a safe minimum, the superheater fires must be secured immediately. On destroyers the superheater fires are usually secured when the speed of the ship drops below 10 knots.

From the standpoint of maintenance and repairs to the steam piping, turbine casings, and superheater handhole plates, it is not feasible to put superheaters into operation until it is expected that the ship's speed will be more than 10 knots for a considerable period of time. Furthermore, continually lighting off and securing the superheater fires will cause extensive steam leaks throughout the system subjected to fast changing temperature conditions. These steam leaks will waste more fuel than could be saved by a few minutes of superheat operation.

The single-furnace boiler without controlled superheat creates a different type of problem. After the boiler is on the line and furnishing steam, there will be sufficient flow because all steam passes through the superheater. When lighting off and securing this type of boiler, there is no normal flow of steam through the superheater and some means of flow must be established. This means that before a boiler is cut in and after it is removed from the line cooling steam must pass through the superheater.

The following brief discussion on the construction and operation of the single-furnace boiler with uncontrolled superheat will help you to understand the need for protection steam during lighting-off and securing operations.

The superheater is installed within the banks of the generating tubes and receives heat from the same fire as the generating tubes. In operation, the steam is generated but before any of it is used, it is routed through the superheater. The steam used for auxiliary purposes must be desuperheated by passing it through a desuperheater that is submerged below the water level in the steam drum or water drum. When the boiler is steaming for auxiliary or underway purposes, there is a constant flow of steam through the superheater, sufficient to cool the superheater tubes. During the time when the boiler is lighted off, before the stops are opened—and also when the boiler is secured, after the stops are closed—there is no normal flow through the superheater. During this time there is heat in the furnace and the superheater tubes are subjected to this heat. If there is no steam flow through the superheater tubes during this period, the superheater will become overheated and damaged. This problem is overcome by piping steam from the auxiliary steam line (150-psi line), through the superheater tubes and into the auxiliary exhaust line.

When the boiler pressure exceeds 150 psi of the auxiliary steam line, steam flow must be provided through the superheater by the use of high pressure drains, auxiliary machinery, and throttling the steam in the auxiliary exhaust line. The amount of oil fired in the boilers during light off should be very carefully controlled to prevent overheating superheater tubes.

It is sometimes necessary to light off and put additional boilers on the line, when a ship is underway. With noncontrol superheat boilers, the steps are much the same as for putting the first boiler or boilers on the line. With superheat control boilers, additional precautions must be taken.

When the steam lines are carrying superheated steam, it would be dangerous to admit saturated steam to the lines. It is not usually possible to establish enough steam flow to light off the superheaters of the incoming boilers, until they are on the line. It is permissible to bring in the incoming boilers, without their superheaters in operation, if the superheater outlet temperature of the steaming boilers is lowered to 600°F. Lowering of the superheat temperature on the steaming boilers should be started in time so that the cutting-in temperature can be reached before the incoming boilers are up to operating pressure. Except in an emergency, the temperature of the superheaters should NOT be lowered or raised at a faster rate than 50°F every 5 minutes.

If the ship is operating at a speed that requires maximum or near maximum superheat temperature and the saturated side is being fired at maximum or near maximum, the officer of the watch must know and inform the bridge that the speed of the ship will have to be reduced in order to cut in additional boilers.

If an emergency exists, it is permissible to attempt to establish flow through the superheaters of the incoming boilers by the following methods: (1) opening the superheater bilge drains, (2) opening the main steam line low pressure drains, (3) opening the main stop bypasses, and (4) steaming the boiler directly to an idle generator (or some installations this cannot be done). If any one or a combination of these measures succeed in establishing sufficient steam flow, the superheaters may be lighted off and the superheat temperature of the incoming boiler brought up to a temperature equal to the temperature of the steaming boilers. None of these measures should be attempted when the speed of the ship can be reduced sufficiently to allow the superheat temperature of the steaming boilers to be lowered to 600°F; these measures may be attempted ONLY in cases of extreme emergency.

The officer of the watch should know the procedure for lighting fires under the superheaters. The casing air pressure is an important factor in lighting these fires. When it is known that superheaters are to be put into use, they should be lighted off before the saturated sides are being fired at a high rate. It is extremely difficult to insert a lighted torch in the superheater furnace when the air casing pressure is high. The torch will almost always be extinguished. Another undersirable result may be flareback which could cause injury to personnel.

OPERATING THE PLANT UNDERWAY

After the ship is clear of the harbor, the commanding officer will order the special sea detail secured. With the ship underway, a considerable amount of attention must be given to the plant. Some of the important factors to be considered are pointed out in the following paragraphs.

OPERATING INSTRUCTIONS

In order to be a good operator, the MM must acquaint himself with all standing orders and operating instructions for his ship. These are made up for each ship and show the various plant arrangements (split plant, cross-connected steaming, cruising arrangement, etc.) for the different speeds. Each watchstander must read and understand the steaming orders and any additional orders issued by the engineer officer.

USING THE CRUISING COMBINATION

A combatant ship operates most of the time at speeds far below maximum. At cruising speeds only a fraction of the turbines' capacity is required. Economy, at lower speeds, is obtained by one of the following methods: (1) by cruising turbines which are designed to operate economically at speeds up to about 18 knots, (2) by cruising stages in the high pressure turbine, and (3) by turbines designed so that they can be operated in series. On turboelectric ships, economy is accomplished by the use of variable speed propulsion motors.

On ships that have a cruising turbine, the cruising combination should be used for all underway operations requiring steady speeds of less than 18 knots. The officer of the watch, or petty officer of the watch, should obtain permission from the OOD to operate on cruising combination whenever possible.

To prevent casualties to cruising turbines, the protective devices (sentinel valve, direct-reading thermometer, crossover valve lock, and thermal alarm) should be checked frequently.

MAIN CONDENSER VACUUM

Maintaining a designed vacuum in the main condenser makes available more useful work from each pound of steam. This increases the maximum speed of the ship. The vacuum for which the turbine was designed must be maintained. Watchstanders must give careful attention to detect and prevent air leaks into the main condensing system. In order to maintain a designed vacuum, the following precautions must be taken:

1. Keep gland packing in good condition.
2. Maintain gland seal steam at the required pressure (usually 1/2 to 2 psig).
3. Eliminate all air leaks into the condensing system.
4. Maintain adequate water in the reserve feed tank which is in use for makeup feed.
5. Ensure that throttles not in use do not leak. Any leakage of steam past a closed throttle will tend to raise the temperature and pressure within turbines not in use.

If the condenser vacuum is not as high as it should be in relation to the condenser load and the cooling water overboard temperature, some part of the condensing system is not functioning properly. The operator should check for malfunctioning of a condensate pump or air ejectors, and for an air leak in some part of the system under vacuum.

ACCELERATION AND DECELERATION CHART

Acceleration and deceleration charts are posted at each main engine throttle board. These charts give the exact amount of time that the throttleman should use in changing speed. When a speed change is ordered, the throttleman can instantly tell, by checking the chart, the minutes and seconds necessary for him to accelerate or decelerate to the new speed. Main engine control has tachometers indicating the number of rpm each shaft is doing. By checking these tachometers, he can coordinate the rpm of the shafts. If one throttleman accelerates or decelerates too fast or too slow, it can be detected and corrected by the officer of the watch.

Improper acceleration or deceleration wastes fuel oil and in general promotes uneconomical operation of the main plant. Each throttleman should make a revolution-pressure table, which gives the approximate pressure required in the first stage of the high pressure turbine to develop a certain rpm. By using this table and the acceleration and deceleration chart, the throttleman can not only promote efficient operation of the plant but also make his watchstanding much easier. There must always be a complete understanding between the engineroom and the bridge as to how many rpm are to be maintained for one-third, two-thirds, standard, and full speed. The throttleman should never relieve the watch without knowing the rpm for these speeds.

SECURING THE MAIN PLANT

After main engine control has been notified of the time that the ship is expected to enter port, advance preparations can be made for entering port, securing the main plant, and setting the auxiliary watch. Personnel must be informed and given specific instructions. On most ships, especially on small ships, the MMC in charge of the watch will supervise the preparations for entering port and the operations that take place. The MMC and MM1 will also be concerned with the administrative procedures involved in bringing a ship into port, securing the main engines, and setting the auxiliary watch.

PREPARING TO ENTER PORT

While the ship is still out in open sea, main engine control should request permission to pump bilges and blow tubes on all steaming boilers. The officer of the watch must keep in mind The Water Quality Improvement Act of 1970. (NOTE: The Acts of 1899 and 1961 remain in effect.) The Water Quality Improvement Act prohibits the discharge of oil by any person from any waterborne ship, onshore facility, or offshore facility, into or upon navigable waters of the United States, adjoining shorelines, or waters of the Contiguous Zone (12 miles). Restrictions within the Contiguous Zone are considerably more strict than those outside the zone. Other features of the Act provide for the control or hazardous substances other than oil and for the control of sewage discharges from ships.

When the bilges have been pumped and tubes blown on all steaming boilers, a report must be made to the bridge. If the ship has fuel oil tanks ballasted with salt water, this oily ballast water will have to be pumped overboard while the ship is well out at sea.

Lowering the Superheat (Controllable Superheat Boilers Only)

It is necessary to lower the temperature of the superheated steam before entering port. Lowering the temperature and securing the superheaters require close cooperation between the bridge, the engineroom and the fireroom. This is especially true on destroyers, where low maneuvering speeds require immediate securing of superheater fires. The fireroom must receive word in sufficient time so that the Boilermen can lower the superheat temperature at the proper rate (superheat should NOT be raised or lowered at a rate greater than 50°F every 5 minutes). When it is desired that the steam temperature be raised or lowered, the fireroom should be notified in sufficient time so that the desired temperature can be reached slowly.

Auxiliary Machinery

On installations where the turbogenerators exhaust to either the auxiliary or main condensers, the following procedure should be used:

1. Put the required auxiliary condensers in operation, and start the required number of ship's service turbogenerators. After sea detail is set, all turbogenerators should be exhausting into their respective auxiliary condensers.
2. Warm up all auxiliary machinery which is to be used in anchoring or mooring the ship.
3. Shift the low pressure drains to the auxiliary condenser. It is usually not good practice to shift the auxiliary exhaust to the auxiliary condenser until the main plant is at least partially secured. In most installations, the auxiliary exhaust will overload the auxiliary condenser, cause a loss of vacuum, and probably result in loss of one or more ship's service turbogenerators. The auxiliary exhaust should be

dumped to the main condensers until it is believed that the auxiliary condenser will not be overheated.

SETTING THE AUXILIARY WATCH

Each ship or class of ships will have its own detailed forms for securing procedures. A procedure used for destroyers is described in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D.

The officer of the watch must coordinate the securing operations. Although securing sheets are provided for each space, the petty officer in charge of the space must secure in accordance with the orders of the officer of the watch. No split-plant valves should be opened or closed without specific orders from the officer of the watch. No machinery, especially ship's service turbogenerators, should be started or stopped without orders from the officer of the watch. No watchstander should take for granted that he knows what is going on in another space. Usually, only the officer of the watch knows what is going on in all spaces.

When the auxiliary watch is set, the officer of the watch or the MMC in charge of the watch will make a final inspection before reporting to the OOD. The status of all machinery must be known by the officer of the watch. He must be able to report to the engineer officer and the OOD that the auxiliary watch is set. which boilers(s) and ship's service generator(s) are in use; and the time of securing boilers, generators, and engines. The officer of the watch should also inform the OOD that the turning gears are engaged and turning, and approximately when they will be secured. The officer of the deck enters this information in the deck log.

The officer of the watch or MMC in charge of the watch must also know what units of machinery, if any, will require repairs, the extent of the repairs, approximately how long the unit(s) will be out of commission, and the length of time that would be required to get the ship underway. This information should be known to all persons concerned, from the men actually doing the work to the commanding officer of the ship. The commanding officer must know at all times how long it would take to get the ship underway and the maximum speed of which the ship is capable. Transmittal of this information starts with the senior petty officer in each space and goes through the chain of command to the commanding officer.

CHAPTER 13

ENGINEERING CASUALTY CONTROL

This chapter presents general information on engineering casualty control—its purpose, the factors involved, and procedures to be followed. Emphasis is placed on the prevention of progressive casualties, the need for correct action to be taken when a casualty occurs, and the importance of cooperation between fireroom and engineroom personnel under casualty conditions.

Engineering casualty control is a phase of damage control. If a review of damage control principles and related information is necessary, see *Basic Military Requirements*, NAVEDTRA 10054-C, *Military Requirements for Petty Officer 3 & 2*, NAVEDTRA 10056-C, *Fireman*, NAVEDTRA 10520-D, *Machinist's Mate 3 & 2*, NAVEDTRA 10524-D, and chapter 9880, *Naval Ships Technical Manual*.

Engineering casualty control is concerned with the prevention, minimization, and correction of the effects of operational and battle casualties to the machinery, electrical, and piping installations. The mission of casualty control is to maintain all engineering services in a state of maximum reliability, under all conditions. The first objective under this mission is the effective maintenance of propulsion machinery, auxiliary and electric power, lighting, interior and exterior communications, fire control, electronic services, ship control, firemain supply, and miscellaneous services (heating, air conditioning, and compressed air). Failure to provide all normal services will affect the ship's ability to function effectively as a fighting unit, either directly (by reducing its power) or indirectly (by reducing habitability) and thereby lowering morale and efficiency of personnel. The second objective—which will contribute to the successful accomplishment of the first—is the minimization of personnel casualties and of secondary damage to vital machinery.

For detailed information, you should familiarize yourself with the *Engineering Casualty Control Manual*, the *Damage Control Book*, the *Ship's Organization Book* and the *Ship's Repair Party Manual*. These publications will vary from ship to ship, but they give the organization and the procedures to be followed in case of engineering casualties to the ship, and other emergency conditions.

FACTORS INFLUENCING CASUALTY CONTROL

The basic factors influencing engineering casualty control are: (1) sound design, (2) inspections, (3) maintenance (including preventive maintenance), and (4) effective organization and training of personnel. Through a combination of these four factors, engineering casualty control reaches a peak of efficiency. CASUALTY PREVENTION is always the most effective form of CASUALTY CONTROL.

Influence of Design

Sound design influences the effectiveness of casualty control in two ways: (1) elimination of weaknesses which may lead to material failure, and (2) installation of alternate or standby means for supplying vital services in the event of a casualty to the primary means.

Both of these factors are employed in the design of naval ships. The second factor is carried out, in the case of individual units, by the installation of duplicate vital auxiliaries; by the use of loop systems and cross connections; and by the installation of complete propulsion plants designed to operate as isolated units (split-plant design).

Preventive Maintenance

Preventive inspections and maintenance are vital to successful casualty control, since they minimize the occurrence of casualties by material failures. Continuous detailed inspection procedures are necessary not only to discover partly damaged parts which may fail at critical times, but also to eliminate the underlying conditions which lead to early failure (improper adjustment, improper lubrication, corrosion, erosion, and other enemies of machinery reliability). Particular attention must be paid to the following external evidences of internal malfunctioning: (1) unusual noises, (2) vibrations, (3) abnormal temperatures, (4) abnormal pressures, and (5) abnormal operating speeds.

Operating personnel should thoroughly familiarize themselves with the temperatures, pressures, and operating speeds of equipment specified for each operating condition, in order that abnormal operating conditions will be more readily apparent. It must not be assumed that an abnormal reading on a pressure gage or a thermometer is caused by an error in the instrument. Each case must be investigated to establish fully the cause of the abnormal reading. Installing a spare instrument, or making a calibration test, will quickly determine if an instrument error exists. All other causes must be traced to their source, if preventive maintenance is to be effective. Some specific examples of advanced warning of ultimate failure are outlined in the following paragraphs.

Because of the safety factor incorporated in pumps, considerable loss of capacity can occur before any external evidence is apparent. Changes in the operating speeds from normal for the existing load in pressure-governor-controlled pumps should be viewed with suspicion. Variations from the normal in chest pressures, lubricating oil temperature, and lubricating oil pressures are indicative of either inefficient operating procedures or poor condition of machinery.

When a material failure occurs in any unit, a prompt inspection should be made of all similar units to determine if there is danger of the same failure. Prompt inspection may eliminate many repeat casualties.

Abnormal wear, fatigue, erosion, or corrosion of a particular part may be indicative of a failure to operate the equipment within its design limits of loading, velocity, and lubrication--or may indicate a design or material deficiency. In the event of a failure of any of the preceding types, a detailed inspection to prevent repeat damage should be undertaken, unless corrective action can be taken which will ensure that such failures will not occur.

Strict attention must be paid to the proper lubrication of all equipment, including frequent inspection and sampling to determine that the correct quantity of the proper lubricant is being used in the unit. It is good practice to make a daily check of samples of lubricating oil in all auxiliary machinery. The samples should be allowed to stand long enough for any water to settle. When units of auxiliary machinery have been idle for several hours, all settled water should be drained from the lowest part of the oil sump, before the unit is started. Replenishment of the oil to the normal working level should be included in this routine. An unusual amount of water in the oil is normally indicative of either poorly fitted or excessively worn carbon packing on turbine-driven pumps.

The presence of salt water in lubricating oil, can be detected by drawing off the settled water and then running a standard chloride test. A sample of sufficient quantity for test purposes can be obtained by adding distilled water to the oil sample. Because of its corrosive effects, salt water in the lubricating oil is far more dangerous to a unit of machinery than is an equal amount of fresh water. Salt water is particularly harmful in the units having ball bearings. Where such units are found to be subject to salt-water contamination of the lubricating oil, it is essential to drain the oil as soon as possible, flush thoroughly, and refill with fresh oil.

Casualty Control Training

Casualty control training must be continuous; it requires step-by-step procedures and constant refresher drills. Drills must be preceded by adequate preparation; then the casualties must be simulated realistically. Supervisory personnel must visualize fully the consequences of any error which may be made in handling simulated casualties originally intended to be of a relatively minor nature. The simulation of major casualties and of battle damage must be preceded by a complete analysis and by careful instruction to all participants. A new crew must be given time to become familiar with the ship's piping systems and equipment prior to simulating any casualty which may have other than local effects.

In the preliminary phase of training, a "dry run" is a useful device for imparting a knowledge of casualty control procedures, without endangering the ship's equipment by too realistic a simulation of a casualty before sufficient experience has been gained. Under this procedure, a casualty is announced, and all individuals are required to report as though action were taken (an indication must be made that the action was simulated). Definite corrective actions can be made, and with careful supervision the timing of individual actions can appear to be very realistic. Regardless of the state of training, such dry runs should always be carried out before any actual attempt is made to simulate realistically any involved casualty. Similar rehearsals should precede relatively simple casualties whenever an appreciable proportion of men, new to the ship, are involved, and particularly after an interruption of regularly conducted casualty training, such as a shipyard overhaul.

Correction of Casualties

The speed with which corrective action is applied to an engineering casualty is frequently of paramount importance. This is particularly true when dealing with casualties which affect the propulsion plant, steering, and electrical power generation and distribution. If casualties associated with these functions are allowed to become cumulative, they may lead to serious damage to the engineering plant; this damage often cannot be repaired without temporary loss of the ship's propulsion power. Where possible risk of permanent damage exists, the commanding officer has the responsibility of deciding whether to continue operating the equipment under abnormal conditions; usually this action can be justified only where the risk of even greater damage, or loss of the ship, may be incurred by immediately securing the affected unit(s). For example, an engineering plant with high salinity could be operated long enough to steam clear of an area of possible enemy attack. However, all possible steps must be taken to shorten the period of hazardous operation.

If there is no probability of risk greater than the damage to machinery, the proper procedure is to secure the malfunctioning unit(s) as quickly as possible, even though loss or a partial loss, of the ship's propulsion power may occur.

Although speed in controlling a casualty is essential, action should never be undertaken without accurate information; otherwise the casualty may be mishandled, and further damage to the ship, or even loss of the ship may result. Cross-connecting an intact plant with a damaged plant must be delayed until it is certain that such action will not jeopardize the intact one. Speed in the handling of casualties can be achieved only by a thorough knowledge of the equipment and associated systems, and by thorough and repeated training in the routine required to handle specific casualties.

Split-Plant Operation

One fundamental of engineering casualty control is SPLIT-PLANT OPERATION. Small combatant ships have two engineering plants and the larger combatant ships have four or more individual engineering plants.

Split-plant operation means dividing boilers, engines, pumps, ship's service generators, and other machinery so that you have either two or more engineering plants—each complete in itself, and each operating its own fuel oil service pumps and source of fuel oil supply. Each turbine installation will operate its own main condenser, air ejectors, lubricating pumps, and other auxiliary machinery when operating split-plant. If one engineering plant (boilers, main engines, or other units of machinery in the specific plant) is put out of commission by explosion, shellfire, or flooding, the other plant(s) can keep the ship underway, though at a reduced speed.

Split-plant operation applies to all piping and electrical systems aboard ship. Split-plant operation is a means of reducing the chance of a casualty that would completely immobilize the entire engineering plant. It prevents a casualty to one plant being transmitted to another plant, or seriously affecting its operation. If a ship were steaming split-plant and a main steam line casualty occurred in one section, main steam would be lost from only one set of boilers; if the plant were cross-connected, steam would be lost from all boilers.

PHASES OF CASUALTY CONTROL

The handling of casualties can be divided into three phases: (1) limitations of the effects of the damage, (2) emergency restoration of services, and (3) complete repair.

The first phase is concerned with immediately controlling the casualty so as to prevent further damage to the unit(s) concerned and to prevent the casualty from spreading through secondary effects.

The second phase consists of restoration, insofar as practicable, of the services which were interrupted as a result of the casualty. When all services are restored, this will, generally, correct all operational difficulties, except for the temporary loss of some standby units. If no damage to, or failure of, machinery has occurred, this phase usually completes the operation.

The third phase of casualty control consists of making repairs which will completely restore the installation to its original condition.

ENGINEERING CASUALTIES

In the event of a casualty to a major component of the propulsion plant, the first consideration should be the prevention of additional or major casualties. Under normal operating conditions, the safety of personnel and machinery should be given first consideration. Where practicable, the propulsion plant should be kept in operation by the use of standby auxiliary machinery and piping systems. The important thing is to prevent minor casualties from becoming major casualties, even if it means a temporary loss of propulsion power. It is better to stop the main engines for a short time than to put them completely out of commission, so that major repairs will be required to place them back in commission.

When a casualty occurs, the engineering officer of the watch, or the petty officer of the watch, [illegible] be notified immediately. Then he notifies the OOD and engineer officer. Main engine control must keep the bridge informed as to the nature of the casualty, the ship's ability to answer bells, the maximum speed available, and probable duration of the casualty.

Engineroom Casualties

For each class of ships, the type commander formulates engineering casualty procedures which are applicable to the specific type of engineering plant. This chapter contains information on typical engineroom casualties and the general procedures recommended by NAVSEA for the control of each. Consult the ship's *Engineering Casualty Control Manual* for engineering casualty procedures on your ship.

High Oil Level in Reduction Gear Case-Oil Emulsion.–If a casualty of this type occurs, the action to be taken is as follows:

SYMPTOMS:

1. Presence of the symptom is the casualty.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Slow engine to 1/3 speed, or stop, if permitted.
3. Employ lubricating oil purifier to pump down sump tank to proper level.
4. Determine cause and correct.
5. Main Engine Control shall:
   a. Notify bridge of casualty, action being taken, and estimated time required to make repairs.
   b. Request permission to adjust ship's speed as necessary.

(NOTE: Emulsion of lubrication oil can be caused by an excessive level as well as the contamination of water. Either cause will be accompanied by a distinct rise in oil temperature.)

Locking and Unlocking of Shaft Underway.–This operation may be considered as a deliberate maneuver rather than a casualty. There are two operations involved in locking the shaft and in unlocking the shaft while the ship is underway.

ACTION TO BE TAKEN:

1. To lock the shaft

a. Slow ship's speed to approximately one-half full power speed or less, or the maximum designated locking speed.

b. Close the ahead throttle and open the astern throttle until the shaft is stopped.

c. Throttleman take note of astern steam pressure required to stop shaft.

d. Engage the turning gear and immediately lock the turning gear motor shaft.

e. Close the astern valve slowly.

f. Throttleman in the unaffected engine-room is to maintain required revolutions as directed by Main Engine Control.

g. DO NOT SECURE lubricating oil to an engine whose shaft is locked while the ship is underway.

2. To unlock the shaft

a. Reduce the temperature of the main steam as much as practicable by cutting out the superheat burners.

b. Bring the ship to the same speed at which the turning gear was engaged. Open the astern throttle to the same pressure as was used in locking process.

c. Disengage the turning gear. (It may be necessary to adjust the astern throttle pressure slightly in order to disengage the turning gear.)

d. When turning gear is disengaged, slowly close the astern throttle.

e. Open ahead throttle slowly and continue underway. (CAUTION: If the shaft is locked for more than five minutes, the turbine rotor may become bowed.)

Piping System Casualties

A rupture in a piping system is another type of casualty that frequently occurs in an engineering space. The corrective action for the particular situation depends on the location and extent of the damage. While all piping system casualties differ in some respects, the following procedures apply to any casualty of this type:

1. Secure the space or isolate damaged sections of system as necessary.

2. Cross-connect systems or plants, where possible, to maintain maximum propulsion power. (CAUTION: Inadvertent cross connection may result in flooding or endanger personnel. Before cross connecting an adjacent space, be sure personnel in that space are aware of action to be taken.)

Main Steam Piping (Split-Plant).—Rupture of main steam piping in any compartment can be expected to fill that compartment with steam to such an extent that it will have to be abandoned and secured from the outside. This will only be required if boiler steam-stop valves cannot be closed. After the compartment has cooled, the damage can be isolated and as much of the plant operated as possible. Power panels may have to be dried out before they can be used.

ACTION TO BE TAKEN:

1. When a section of main steam piping is carried away in a fireroom

a. Notify Main Engine Control and keep them informed.

b. Close main boiler stop valve(s) by remote control and throttle valve on affected engine(s). The latter action will prevent loss of vacuum.

c. Stop fuel to burners by closing master fuel valve or by remote control. This action can be accomplished by activating the quick-closing valve at the boiler fuel oil manifold.

d. Secure fuel oil pumps.

e. Isolate all steam lines to the damaged area.

f. Open cross-connection valves to restore main and auxiliary steam service to main engines, turbo-generators, and auxiliaries. Cross-connect fresh water drain in condensate system to return water to the plant supply steam.

(NOTE: Maximum speed in restoring lubricating oil pressure is essential.)

2. Major break in main steam piping in engineroom.

a. Notify Main Engine Control and keep them informed.

b. Close main and auxiliary boiler stop valve(s).

c. Shut off fuel to burners by closing master fuel valve.

d. Secure fuel oil pumps.

e. Isolate necessary piping to damaged area.

f. Light off and restore service available.

3. Break in main steam piping in engineroom (compartment not instantly untenable.)

a. Notify Main Engine Control and keep them informed.

b. Close main boiler stop valve(s) in fireroom. Main steam bulkhead cut-out valves could also be closed. (During split-plant operation they are closed.)

c. Close main throttle(s) in engineroom.

d. Secure fuel oil pumps.

e. Isolate ruptured section of main steam piping.

f. Auxiliary steam is continued to the engineroom if possible, in hope of maintaining lube oil pressure. This is not necessary if shaft-driven or electric lube oil pumps are installed.

g. Lock trailing shaft(s) as necessary.

h. Isolate piping and resume use of engine(s) if possible.

Rupture in Auxiliary Steam Piping.—Rupture of a section of auxiliary steam piping will probably fill the compartment with steam to such an extent that it will have to be abandoned and secured from the outside.

ACTION TO BE TAKEN:

1. When section of auxiliary steam piping in fireroom is carried away.

a. Notify Main Engine Control and keep them informed.

b. Shut off fuel supply to burners by closing master fuel valve by remote control.

c. Secure fuel oil pumps.

d. Close the main and auxiliary boiler stop valves by remote control.

e. Isolate main and auxiliary steam piping to damage fireroom.

f. Open cross connection valves to restore main and auxiliary steam service to main engines, turbo-generators, and auxiliaries.

g. When possible, isolate damage and resume operation of damaged fireroom.

2. When a section of auxiliary steam piping ...ied away in the engineroom

a. Notify Main Engine Control and keep them informed.

b. Stop and lock the shaft to prevent rotation, if practicable.

c. Isolate the damaged system by closing bulkhead or line-stop valves as applicable.

d. Isolate damaged section of auxiliary steam piping.

e. Resume operation of fireroom and engineroom as soon as possible.

Rupture in Auxiliary Exhaust Piping.—In low pressure systems, patches, blank flanges, or plugs may be used freely, and the system operated even though damaged. In the event of a major break, take action similar to that for a rupture in the auxiliary steam piping.

1. When a section of auxiliary exhaust piping is ruptured in the fireroom

a. Notify Main Engine Control and keep them informed.

b. Observe closely the operating condition of the deaerating feed tank to prevent a feed casualty.

c. Isolate section of damaged piping, venting it through the atmosphere exhaust. Use only necessary machinery which exhausts into the damaged section.

d. Make repairs to damaged piping.

2. When a section of auxiliary exhaust piping is ruptured in engineroom

a. Notify Main Engine Control and keep them informed.

b. Observe closely the operating condition of the deaerating feed tank to prevent a feed casualty.

c. Isolate section of damaged piping, venting where practicable, through the atmosphere exhaust.

d. Make repairs or replace damaged piping.

Fireroom Casualties

As an MM1 or MMC, you will be concerned with various fireroom casualties. In general, the Boiler Technician is responsible for taking the necessary steps to control fireroom casualties. However, it will become necessary for the Machinist's Mate to carry out proper procedures to control the casualties which have a direct effect on the operation of the engineroom. Close cooperation between the engineroom and fireroom personnel is necessary for the most efficient handling of engineering casualties.

Under all circumstances, the Boiler Technician will notify the engineroom of the fireroom casualties. The necessary action that must be taken will be based on the report given by the Boiler Technician. When a fireroom casualty affects the operation of the engineroom, cooperation and communication between personnel of both the spaces are extremely important. Lack of (or improper) communication or cooperation can be the indirect cause of a casualty getting out of control and resulting in serious damage to machinery and injury to personnel. Main engine control must receive all important information in order to coordinate the handling of the casualty. Main engine control must have all vital information to keep the officer of the deck informed as to the status of the machinery and the maximum speed the ship can make.

For additional information on fireroom casualties, see *Machinist's Mate 3 & 2*, NAVEDTRA *10524-D*.

Battle Casualties

As an MM1 or MMC, you will be responsible for knowing how to handle battle casualties. Speed is a critical factor when applying corrective procedures to battle casualties. But speed is not the only factor to be considered. CORRECT ACTION must be taken. Thorough training of all personnel concerned is essential in applying proper procedures in handling battle casualties.

This training manual contains information on some of the different types of battle casualties. Battle casualty control procedures are extremely important; and an MM1 or MMC will be expected to know them. You must be familiar with the procedures as presented both in this training manual and in other publications that cover them in greater detail. *NAVSHIPS Technical Manual*, chapter 9880 and your own ship's *Damage Control Book*, *Engineering Casualty Control Manual*, and *Ship Repair Party Manual* are publications which contain very important information which you must know.

Shell or torpedo hits in engineering spaces usually result in multiple casualties to machinery and systems. The corrective action for any particular casualty depends on the location and extent of damage. While battle casualties differ in many respects, the following procedures apply to any casualty of this type:

1. Secure the space or isolate damaged sections, as practical.
2. Cross-connect systems or plants when possible.
3. Stop and lock the shaft—in the event of serious damage to the turbine, reduction gear, main steam line, or the main shaft, or in the event of loss of lubricating oil pressure to the main engines.
4. Carry out applicable casualty control procedures in the event of damage to machinery or piping systems.
5. Take all precautions to prevent flooding of the space. Put all available pumps on the bilges of the damaged space; plug all holes and if possible, prevent flooding of other spaces. (Note: The main condenser circulating pumps are provided with a bilge suction which has the largest potential capacity available for pumping engineroom bilges. If a main circulating pump operates on bilge suction, it should be started the same as for main condenser circulating service, the bilge suction valve should be opened, and the sea suction valve gradually closed. When the pump is operating on a high suction lift, as when pumping bilges, the speed should be reduced to approximately 2/3 of rated speed. Pump noise can be minimized by slowing the pump.)
6. Lube oil lines, fresh water lines, salt water cooling mains, auxiliary exhaust lines and other low pressure lines may be repaired by the use of soft patches, blank flanges, wooden plugs, or other suitable means.
7. If a ruptured steam line prevents entry of repair party personnel into a space, the space may be secured by remote controls.
8. Fires should be extinguished and damage should be investigated as soon as possible.
9. Make repairs to return machinery or the space back to service, if possible.
10. Keep communication lines open and keep main engine control advised of the existing conditions.

CHAPTER 14

INSPECTIONS AND TRIALS

The Chief of Naval Operations and the type commanders require that certain engineering inspections and trials be conducted in order to determine that required standards are being maintained and to accurately evaluate the operational readiness of the ship. The frequency with which the various types of inspections are held is determined by CNO, the fleet commander, and the type commander. As far as the ship is concerned, the type commander usually designates the type of inspection and when it will be held.

A ship is frequently notified some time in advance when an inspection will take place, but preparation for an inspection should not be postponed until the notice of inspection is received. It is a mistake to think that a poorly administered division or department can, by a sudden burst of energy, be prepared to meet the inspector's eagle eye. By using proper procedures, and keeping up to date on such items as repair work, maintenance work, operating procedures, training of personnel, engineering casualty control drills, maintenance records, operating records, and other records and reports, you will always be ready for an inspection.

Your ship may be required to furnish the inspecting party that will make an inspection on another ship. Should this occur, you as a CPO or PO1 may be assigned the duty as an assistant inspector. Therefore, you should know something about the different types of inspections and how they are conducted.

ADMINISTRATIVE INSPECTION

Administrative inspections cover administrative methods and procedures normally employed by the ship, and each inspection is divided into two general categories—the general administration of the ship as a whole, and the administration of each department. In this discussion we will consider the engineering department only.

The purpose of the administrative inspection is to determine (1) that the department is being administered in an intelligent, sound, and efficient manner, and (2) that the organizational and administrative methods and procedures are directed toward the objective of every naval ship—namely, being prepared to carry out her intended mission.

INSPECTING PARTY

It is a routine procedure for one ship to conduct an inspection on another ship within the division. General instructions for conducting the inspection are usually given by the division commander; however, the selecting and organizing of the inspecting party is done aboard the ship that has received instructions to conduct the inspection.

The Chief Inspector, usually the commanding officer of the ship, will organize the assisting board. The organization of the assisting board is in general conformance with the departmental organization of the ship. It is divided into appropriate groups, each headed by an inspector with assistant inspectors as necessary. Chief petty officers and petty officers first class may be assigned as assistant inspectors.

The engineering department inspecting group (or party) will be organized and supervised by the engineer officer. The manner in which the inspection will be carried out will depend to a great extent upon the knowledge and ability of the assistant inspectors.

GENERAL INSPECTION OF THE SHIP

One of the two categories of the administrative inspection is that of the general administration of the ship as a whole. Items of this inspection that will have a direct bearing on the engineering department, and for which the report of inspection indicates a grade, are as follows:

1. Appearance, bearing, and smartness of personnel.
2. Cleanliness, sanitation, smartness, and appearance of the ship as a whole.
3. Adequacy and condition of clothing and equipment of personnel.
4. General knowledge of personnel in regard to the ship's organization, ship's orders, and administrative procedures.
5. Dissemination of all necessary information among the personnel.
6. Indoctrination of newly reported personnel.
7. General eductional facilities for individuals.
8. Comfort and conveniences of living spaces, including adequacy of light, heat, ventilation, and fresh water, with due regard for economy.

ENGINEERING DEPARTMENT INSPECTION

The administrative inspection is primarily an inspection of the engineering department paper work, which includes numerous publications, bills, files, books, records, and logs. However, the inspection will also include other items with which the chief and first class will be concerned. Some of these items are the cleanliness and preservation of machinery and engineering spaces; training of personnel; assignment of personnel to watches and duties; the proper posting of operating instructions and safety precautions; adequacy of warning signs and guards; the marking and label of lines and valves; and the proper maintenance of operating logs.

ADMINISTRATIVE INSPECTION CHECKOFF LISTS

Administrative inspection checkoff lists are usually furnished to the ships by the type commander. These lists are used as an aid for inspecting officers and chiefs, o assist them in ensuring that no important iten is overlooked. Inspecting personnel should not accept these lists as being all-inclusive. It usually develops, during an inspection, that there are additional items to be considered or observed.

As a petty officer, you should be familiar with the various checkoff lists used for inspections. The checkoff lists will give you a good understanding of how to prepare for an inspection as well as how to carry out your daily supervisory duties. You will find it helpful to obtain copies of the various inspection checkoff lists from the log room and to carefully look them over. They will give detailed information for your type of ship.

You can get a better understanding of the scope and purpose of administrative inspection, as compared to other types of inspections, from the following abbreviated sample of an engineering department checkoff list:

1. BILLS FOR BOTH PEACE AND WAR:

a. Inspect the following, among others, for completeness, correctness, and adequacy:

(1) Department Organization.
(2) Watch, Quarter, and Station Bills.
(3) Engineering Casualty Bill.
(4) Fueling Bill.

2. ADMINISTRATION AND EFFECTIVENESS OF TRAINING:

a. Administration and effectiveness of training of personnel for current and prospective duties.

(1) Are sufficient nonrated men in training to replace anticipated losses?

(2) NAVEDTRA training courses:

(a) Number of men enrolled.

(b) Percentage of men in department enrolled

(c) Number of men whose courses are completed.

(3) Are personnel concerned familiar with operating instructions and safety precautions? (Question personnel at random.)

(4) Are personnel concerned properly instructed and trained to handle casualties to machinery?

(5) Are personnel properly instructed and trained in damage control?

(6) Are training films available and used to the maximum extent?

(7) Are training records of personnel adequate and properly maintained?

3. DISSEMINATION OF INFORMATION WITHIN DEPARTMENT:

a. Is necessary information disseminated within the department and divisions?

b. Are the means of familiarizing new men with department routine orders and regulations considered satisfactory?

4. ASSIGNMENT OF PERSONNEL TO STATIONS AND WATCHES:

a. Are personnel properly assigned to battle stations and watches?

b. Are sufficient personnel aboard at all times to get the ship under way?

c. Are men examined and qualified for important watches?

d. Does it appear that men on watch have been properly instructed? (Question personnel at random.)

5. OPERATING INSTRUCTIONS, SAFETY PRECAUTIONS, AND CHECK-OFF LISTS:

a. Inspect completeness of the following:

(1) Operating instructions posted near machinery.

(2) Posting of necessary safety precautions.

b. Is the operation of the 3-M System properly maintained?

c. Are responsible personnel familiar with current instructions regarding routine testing and inspections?

d. Are lighting-off and securing sheets properly used?

6. PROCEDURES FOR PROCUREMENT, ACCOUNTING, INVENTORY, AND ECONOMY IN USE OF CONSUMABLE SUPPLIES REPAIR PARTS AND EQUIPAGE:

a. Is an adequate procedure in use for [illegible]ement of repair parts?

b. Are there adequate measures used to prevent excessive waste of consumable supplies?

c. Is there proper supervision in the proper supply of, care of, and accountability for hand tools?

d. Are inventories taken of repair parts which are in the custody of the engineering department?

e. How well are repair parts preserved and stowed?

f. What type of system is used to locate a repair part carried on board? (Have a chief or first class petty officer explain to you how he would obtain a repair part for a certain piece of machinery.)

g. Are custody cards properly maintained for accountable tools and equipment?

7. MAINTENANCE OF RECORDS AND LOGS:

a. Inspect the following for compliance with pertinent directives, completeness, and proper form:

(1) Engineering Log.
(2) Bell Book.
(3) Operating records.
(4) Maintenance records.
(5) Alteration and Improvement Program.
(6) Daily Oil and Water Records.
(7) Engineering Reports.
(8) Training Logs and Records.
(9) Work Books for Engineering Spaces.

8. AVAILABILITY AND CORRECTNESS OF PUBLICATIONS, DIRECTIVES AND TECHNICAL REFERENCE MATERIAL:

a. Engineering Blueprints Recommended:
(1) Ship's Plan Index (SPI).
(2) Proper indexing of blueprints.
(3) Completeness and condition.
b. Manufacturers' Instruction Books:
(1) Proper indexing.
(2) Completeness and condition.
c. Type Commanders Material Letters.
d. NAVSHIPS Technical Manual.
e. General Information Book.
f. Booklet Plans of Machinery.

9. CLEANLINESS AND PRESERVATION:

a. Preservation and cleanliness of space (including bilges).
b. Preservation and cleanliness of machinery and equipment.
c. Neatness of stowage.
d. Condition of ventilation.
e. Condition of lighting.
f. Compliance with standard painting instructions.

OPERATIONAL READINESS INSPECTION

The Operational Readiness Inspection (ORI) is conducted to evaluate the offensive and defensive capabilities of the ship based on the state of training of the crew and the material condition of the ship.

The inspection will consist of the conduct of a battle problem problem and other operational exercises. A great deal of emphasis is placed on gunnery, damage control, engineering casualty control and other appropriate exercises. Various drills are held and observed. The ship will be operated at full power for a brief period of time.

The overall criteria of performance include:

1. Can the ship as a whole carry out her operational functions?
2. Is the ship's company well trained, well instructed, competent, and skillful in all phases of the evolutions?
3. Is the ship's company stationed in accordance with the ship's Battle Bill, and does the Battle Bill meet wartime requirements?

OBSERVING PARTY

The personnel and organization of the operational readiness observing party will be about the same as that of the administrative inspection party. However, more personnel are usually required in the operational readiness observing party, and these additional personnel are very often chiefs and first class petty officers.

The observing party members should be briefed in advance of the scheduled exercises and drills that are to be conducted. The observers must have sufficient training and experience so that they can properly evaluate the exercises and drills that are to be held. Each observer will usually have an assigned station. He should be well qualified in the procedure of conducting drills and exercises for that station. It is highly desirable that each observer be familiar with the type of ship to be inspected.

BATTLE PROBLEMS

In this discussion we will consider the battle problem from the viewpoint of the observer, and present some general information on the requirements and duties of a member of the engineering department observing party. Then, knowing the viewpoint and duties of an observer, you can prepare yourself and your men for a battle problem and other appropriate exercises.

Preparation of a Battle Problem.—The degree of perfection achieved in any battle problem is a direct reflection of the skill and application of those who prepare it. A great deal depends upon the experience of officers and chief petty officers.

The primary purpose of a shipboard battle problem is to provide a medium for testing and evaluating the ability of all divisions of the engineering department to function together as a team in simulated combat operations in order to accomplish the mission assigned by the problem.

Battle problems can be made the most profitable and significant of all peacetime training experience, since they demonstrate how ready a department is for combat. The degree of realism of this test governs its value; the more nearly it approximates actual battle conditions, the more valuable it is.

Conduct of a Battle Problem.—There is one element in conducting a battle problem which increases its value to the ship's company: the element of surprise. Of course, preparations for carrying out a problem can't be kept entirely a secret. Before a battle problem is to be conducted, the ship is furnished information such as:

1. Authority for conducting the inspection.
2. Time of boarding of the inspecting party.
3. Time ship is to get underway.

4. Time for setting the first material readiness condition.
5. Time of conducting inspection for zero problem time conditions.
6. Zero problem time.
7. End of problem time.
8. Time to critique.

Observers should be proficient in the proper methods of introduction of information. In general, information delivered to ship's personnel should be verbal when practicable, and only that information which ship's personnel would logically determine from procedure and adequacy of investigation on search should be furnished by the observer. Should the inadequacy of procedure by ship's personnel result in the nondiscovery of a casualty imposed, observers may resort to coaching, but a notation should be made on the observer's form as to the time allowed before coaching and information were furnished. Special precautions should be taken to give the symptoms of casualty the same degree of realism that they would have if the casualty were actual rather than simulated.

In order to impose casualties, valves may have to be closed, switches opened, or machinery stopped. In each cases the observer should inform responsible ship's personnel of the action desired, and the ship's personnel should operate the designated equipment. A casualty should be simulated, or omitted entirely, if there is danger that personnel injury or material damage might result because of lack of preparation or experience of personnel concerned. The supply of lubricating oil to the main engines or the supply of feed water to the boilers MUST NOT be stopped to simulate casualties.

An emergency procedure is set up, by the observing party and ship's company, to take proper action in case actual casualties as distinguished from simulated or problem casualties should occur.

The general announcing system (the 1MC circuit) may be used by the ship but observers normally will have priority in its use. The problem time announcer will use the general announcing system to announce the start of the battle problem, the problem time at regular intervals, the conclusions of the problem, and the restoration of casualties. However, the general announcing system is kept available at all times for use in case of actual emergency. All other announcing system circuits and all other means of interior communications are reserved for the use of the ship.

Engineering telephone circuits should be monitored by one or more observers. A check should be made for proper procedure and circuit discipline, and for handling of information or casualties.

An inspection should be made to see that the engineering plant is properly split in accordance with current directives. Any fire hazards such as paint, rags, or oil should be noted. Check for missile hazards such as loose gear, loose floor plates, tool boxes, and repair parts boxes. The condition of fire fighting, damage control, and remote control gears should be carefully inspected.

Analysis of the Battle Problem.–The maximum benefit obtained from conducting a battle problem lies in the determination of existing weaknesses and deficiencies, and the resulting recommendations for improvement in organization and future training. Every effort should be made by observers to determine excellencies as well as deficiencies; a knowledge of existing excellencies by ship's personnel is helpful to moral and indicates those factors that presently, at least, may receive less emphasis in the shipboard training program.

Analysis of the battle problem affords the observers an opportunity to present to the ship their opinion of her performance, and for the ship to comment on the observers' remarks and to consider suggested improvements in doctrine or material. Analysis is conducted in two steps: the critique and the observers' reports.

A critique of the battle problem should be held on board the observed ship before the observing party leaves, in order that a review of the problem and the action taken may be made when both are fresh in the minds of all concerned. The critique is attended by all the ship's officers, appropriate chief and first class petty officers, the Chief Observer, and all Senior Observers. The various points of interest of the battle problem are discussed, and the Chief Observer comments on the overall conduct of the problem after the Senior Observers have completed their analysis of the battle problem as developed from their observers' reports.

The observers' reports will be in the form prescribed by the type commander, and will include any additional instructions given by the Chief Observer. The reports of the observers are collected by the Senior Observer for each department. Senior Observers submit their reports to the Chief Observer All observers' reports are reviewed by the Senior Observer for the requisite department before the critique is held.

The observers' reports also serve to furnish the inspected ship with detailed observations of the battle problem which may not, because of time limitations, be brought out during the critique. The inspected ship receives a copy of all observers' reports; in this way, each department is given the opportunity to view the detailed comments and to set up a training schedule to cover weak points.

A brief example of an engineering observer's report form is given as follows:

Engineering Observer . . . .
Location . . . .

1. The engineering department's evaluation is based on: (a) extent of the department's preparation and fulfillment of the ordered conditions of readiness as appropriate to the problem, (b) extent of correct utilization of the engineering damage control features built into the ship, (c) extent to which proper engineering casualty control is accomplished, (d) extent to which on-station personnel take corrective action for control of damage, (e) adequacy of reports and dissemination of information, and (f) the general handling of the plant in accordance with good engineering practice, and the ability of the department to ensure maximum mobility and maneuverability of the ship and to supply all necessary services to other departments in fighting the ship.

2. Hit. . . . .
Exercise. . . .
a. Preparation and status of the plant.
b. Fulfillment of proper conditions of readiness.
c. Fire and missile hazards.
d. Condition of firefighting and damage control gear.
e. Condition of personnel clothing and protection.
f. Stationing and readiness of personnel.
g. Investigation and interpretation of casualty.
h. Promptness and effectiveness in taking care of casualty.
i. Were proper doctrine and procedures used?
j. Where prompting and additional information given by observer?
k. Were proper reports made?
l. Readiness of standby units.
m. Readiness of alternate and emergency lighting and power.
n. Were proper safety precautions observed?
o. Material deficiencies.
p. Coordination of personnel.
q. Coordination of engineering spaces.

3. Main Engine Control. Receipt of vital interior communications, origination and transmissions of required reports to Conn, Damage Control Central, and other stations.

4. Action taken by main engine control:
a. Correct action.
b. Sound judgment based on good practice.
c. Assurance.
d. Speed.

5. Recommendations.

The blank parts of the observers' report forms are filled in as applicable to the individual observer's station. Items that were not observed by him are either left blank or crossed out. Additional information, if required for a certain exercise or condition, may be written on the reverse side of the form. A separate form or sheet is used for each exercise or drill Remarks or statements made by the observer should be clear and legible.

MATERIAL INSPECTION

The purpose of material inspection is to determine the actual material condition of the ship in regard to the ability to perform all functions for which the items were separately and interrelatedly designed. On the basis of what the inspection discloses, it may be necessary to recommend repairs, alterations, changes, or developments which will ensure the material readiness of the ship to carry out the mission for which she was designed. In addition, the material inspection determines whether or not proper procedures have been carried out in the care and operation of machinery and equipment. Administrative procedures and material records which are inspected include such items as maintenance records and routine tests and inspections.

In brief, the prescribed requirements for material readiness are as follows:

1. Established routines for the conduct of inspections and tests, schedules for preventive maintenance, and a system which will ensure timely and effective repairs.

2. Adequate material maintenance records, that are kept in accordance with current directives and that will give the history and detailed condition of machinery and equipment.

3. Planned and effective utilization of the ship's facilities for preservation, maintenance, and repair.

4. Correct allocation of necessary work to the following categories, (a) the ship's force, (b) the tenders and repair ships, and (c) the naval shipyards or other shore repair activity.

The scope of the inspection will be similar to that of inspections made by the Board of Inspection and Survey. (These inspections are discussed later in this chapter.) The inspection should be thorough and searching, and cover detailed maintenance and repair rather than general appearance. The distinction between administrative inspections and material inspections should be clearly recognized, and there should be as little duplication as possible. An examination of the material maintenance records and reports will be made to obtain data and material history for a proper understanding of the material condition of machinery and equipment. General administrative methods, general appearance, cleanliness of compartments, and cleanliness of machinery are not part of this inspection, except in cases where they have a direct bearing on material condition. Special painting should not be done solely in preparation for material inspection.

The inspecting party for the material inspection is similar to that of the administrative inspection party.

PREPARATION FOR THE INSPECTION

At an appropriate time prior to the date of the inspection the Chief Inspector will furnish the ship with advance instructions, including:

1. List of machinery and major equipment to be opened for inspection. The limit that a unit of machinery or equipment should be opened is that which is necessary to reveal known or probable defects. The units selected to be opened should be representative and, in a multiple-shaft ship, should not disable more than one-half of the propulsion units. Proper consideration must be given to the ship's operational schedule and safety.

2. List of equipment to be operated. Auxiliary machinery such as the anchor windlass, winches, and steering gear are normally placed on this list.

3. Copies of the condition sheets. This is a form of checkoff list which is used for the material inspection.

4. Any additional instructions considered necessary by the type commander or other higher authority.

Condition Sheets.–Condition sheets are made up in accordance with different material groups. The engineering department will be primarily concerned with the machinery, the electrical, the damage control, and the hull condition sheets. Condition sheets contain material in form of checkoff sheets and material data sheets and consist of a large number of pages. Items for data and check-off purposes are listed for all parts of the ship, and for all machinery and equipment on board ship.

In advance of inspection, the ship to be inspected must fill in a preliminary copy of the condition sheets. In order to accomplish this, detailed data must be obtained from the maintenance records and reports.

An entry of any known fault or abnormal

condition of machinery or equipment is made, in the proper place on the condition sheets. Details and information are given, as necessary, to indicate the material condition to the inspecting party. Data and information requested in the condition sheets should be furnished whenever possible. The preliminary copy, if properly filled out, will represent the best estimate as to the existing material condition of the ship.

When the condition sheets have been completed, they are turned over to the respective members of the inspecting party upon their arrival on board ship. During the inspection, the inspectors will fill in the various check-off sections of the condition sheets. These sheets are then used in preparing the final inspection report on the condition of the ship.

For more detailed information concerning your ship, you should obtain a copy of the applicable condition sheets from the engineering log room.

Opening Machinery for Inspection.–The ship will open machinery as previously directed by the Chief Inspector, and as considered desirable, in order to obtain the inspector's opinion concerning known or probable defects.

More detailed information on opening machinery for material inspections will be found in the administrative letters of the type commander.

A list of machinery, tanks, and major equipment opened, and the extent of opening, should be supplied to the inspecting party on its arrival. Test reports on samples of lubricating oil should be furnished to the machinery inspector.

Ship's company should have po table extension lights rigged up and in readiness for the units of machinery opened up for inspection. The lighting of the space should be in good order. The inspectors should be furnished flashlights, chipping hammers, file scrapers, and similar items. Precision measuring instruments should be readily available.

Assembly of Records and Reports.–The material inspection also includes an inspection of various material records and reports. These documents are assembled so that they will be readily available for inspection. Records should be kept up to date at all times; it is a good idea to check over all records to make sure that they ARE up to date and that nothing has been overlooked. The individual records should be filled out and maintained in accordance with current directives. Where applicable, the petty officer in charge of an engineering space, or other assignment, should check on any records or reports that concern the material or the maintenance procedures of his space or assignment.

CONDUCT OF THE INSPECTION

The inspecting group for the engineering department should conduct a critical and thorough inspection of the machinery and equipment under the cognizance of the department. The condition sheets supplied by the type commander serve as a guide a check-off list in making the inspection. Appropriate remarks, comments, and recommendations are entered on the condition sheets for the particular unit of machinery or equipment.

The inspectors should conduct the inspection with the ship's personnel. No attempt is made to follow a predetermined inspection schedule, but different units are inspected as they are made available by ship's company. If the ship is prepared for the inspection there should be no delay between the inspection of the different units of machinery. It is not necessary that all machinery of one type be inspected simultaneously nor is it necessary to complete the inspection of one space before going to another.

Important items to be covered by the inspection are as follows:

1. All opened machinery and equipment should be carefully inspected, especially where the need of repair work is indicated on the work list.
2. An investigation should be made to locate any defects, in addition to those already known, that may exist in material condition or design.
3. Operational tests of machinery and equipment, in accordance with the furnished list, are observed.
4. Ensure that electrical equipment is not endangered by salt water from hatches, doors, or ventilation outlets. Check for possible leaks in piping flanges.

5. Ensure that currently required firefighting and damage control equipment in the engineering space is installed and properly maintained in accordance with current directives.

6. Inspect the supports and running gear of heavy suspended material.

7. Inspect hold-down bolts, plates, and other members of machinery foundations. Make free use of hammers for sounding, and of file scrapers for removing paint in order to disclose any condition of metal corrosion.

8. The condition sheets should be checked to see that all the required information has been filled in by the ship being inspected, and that all items have been checked off and filled in by the inspector.

9. Ensure that routine tests of mechanical and electrical safety devices are being conducted according to current directives.

10. The maintenance records and reports should be carefully inspected to see that they are maintained in accordance with prescribed procedures. A check should be made to see that all known repair requirements are listed.

ANALYSIS AND REPORTS

A critique should be held on board the inspected ship, at a convenient time after the completion of the material inspection, in order that the ship may derive the greatest benefit from the inspection. It should be attended by the ship's commanding and executive officers, heads of departments, and such other personnel as may be designated from the inspected ship, the Chief Inspector, and inspectors of each inspection group.

The inspectors, after receiving data from the assistant inspectors, submit reports of their inspections to the Chief Inspector. These reports provide a means of furnishing the inspected ship with those observations that may not be fully discussed during the critique but are of interest to the ship's officers concerned. The inspector's report should include his evaluation and any recommendations for the items inspected or observed. These reports can be used by the ship as a check-off list for corrective action and material improvement.

The Chief Inspector, after receiving the reports from the inspectors, will make up his report, evaluating and grading the inspection. The Chief Inspector should mention, with appropriate comment, the following:

1. Those conditions requiring remedial action which should be brought to the attention of the commanding officer of the ship inspected, and to higher authority.

2. Those conditions of such excellence that their dissemination will be of value in improvements to other ships.

3. Those suggestions or recommendations which merit consideration by higher authority.

The final smooth report is written up in a detailed procedure in accordance with the type commander's directives.

BOARD OF INSPECTION AND SURVEY INSPECTION

The Board of Inspection and Survey is under the administration of CNO. This board consists of a flag officer, as president, and of such other senior officers as may be required to assist him in carrying out the duties of the board. Regional boards and sub-boards are established, as necessary, to assist the Board of Inspection and Survey in the performance of its duties. In this discussion we are considering the shipboard inspections that are made by the sub-boards. These sub-boards consist of the Chief Inspector and about 10 or more members, depending upon the type of ship that is to be inspected.

MATERIAL INSPECTIONS BY BOARD

The inspection made by the Board of Inspection and Survey is in several respects similar to the Material Inspection that has just been discussed. In fact, the Board of Inspection and Survey's inspection procedure, condition sheets, and reports are used as guides in establishing directives for the Material Inspection. The primary difference, in regard to material inspections, is that the Material Inspection is conducted by Forces Afloat, usually a sister ship, and the Board of Inspection and Survey Inspection is conducted by a specially appointed board. This distinction, however, refers only to the routine shipboard material inspection. It must be remembered that the Board of Inspection and Survey conducts other types of inspections which are of a different nature.

Inspections of ships are conducted by the Board of Inspection and Survey, when directed by CNO, to determine their material condition. This inspection usually takes place 4 to 6 months prior to regular overhaul. Whenever practicable, such inspections should be held sufficiently in advance of a regular overhaul of the ship to permit accomplishment, during such overhaul, of the authorized work resulting from the Board's recommendations. Upon the completion of its inspection the Board will report the general condition of the ship and its suitability for further naval service together with a list of the repairs, alterations, and design changes which, in its opinion, should be made.

ACCEPTANCE TRIALS AND INSPECTIONS

Trials and inspections are conducted by the Board of Inspection and Survey on all ships prior to final acceptance for naval service, to determine whether or not the contract and authorized changes thereto have been satisfactorily fulfilled. The builder's trials and acceptance trials are usually conducted before a new ship is placed in commission. After commissioning, a final contract trial is held. Similar inspections are made on ships that have been converted to other types. All material, performance, and design defects and deficiencies found to exist, either during the trials or as a result of examination on completion of trials, are reported by the Board, together with its opinion as to the responsibility for correction of defects and deficiencies. The Board will recommend any changes in design which it believes should be made in the ship or in others of its type. Recommendations as to the acceptance or rejection of the ship are made to the Secretary of the Navy.

Unless war circumstances prevent, the acceptance trial takes place at sea. Tests include full power runs ahead and astern, quick reverse, boiler overload, steering, and anchor engine. During the trial, the builder's personnel usually operate the ship and her machinery. Ship's personnel who are on board to observe the trial should carefully inspect the operation and material condition of machinery and equipment. Any defects or deficiencies should be noted and brought to the attention of division or engineer officer, so that the items can be discussed with the appropriate members of the Board of Inspection and Survey.

SURVEY OF SHIPS

Survey of a ship is conducted by the Board of Inspection and Survey whenever a ship is deemed by CNO to be unfit for further service, because of material condition or obsolescence. The Board will, after a thorough inspection, render an opinion to the Secretary of the Navy as to whether the ship is fit for further naval service, or can be made so without excessive cost.

If the Board believes that the ship is unfit for further naval service, the Board will make appropriate recommendations as to the ship's disposition.

SHIP TRIALS

There are a number of different types of trials which are carried out under specified conditions. To convey a general idea of the different trials, a list comprising most of them is given here:

1. Builder's trials.
2. Acceptance trials.
3. Final contract trials.
4. Post repair trials.
5. Laying up or pre-overhaul trials.
6. Recommissioning trials.
7. Standardization trials.
8. Tactical trials.
9. Full power trials.
10. Economy trials.

The trials that are considered to be routine ship's trials are numbers 4, 9, and 10 of the above list. Post repair, full power, and economy trials are the only ones discussed in this chapter, but information on the other types of trials can be found in chapter 9080 of NAVSHIPS Technical Manual.

POST REPAIR TRIAL

The post repair trial should be made whenever the machinery of a vessel has undergone extensive overhaul, repair, or alteration which may affect the power or capabilities of the ship or the machinery. A post repair trial is usually made when the ship has completed a routine naval shipyard overhaul period; the trial is OPTIONAL whenever machinery has undergone only partial overhaul or repair. The object of this trial is to ascertain if the work has been satisfactorily completed and efficiently performed, and if all parts of the machinery are in every respect ready for service.

The post repair trial should be held as soon as practicable after the repair work has been completed, the preliminary dock trial made, and the persons responsible for the work are satisfied that the machinery is in all respects ready for a full power trial. The conditions of the trial will be largely determined by the character of the work that has been performed. The trial should be conducted in such manner as the CO and commander of the shipyard may deem necessary. In cases where repairs have been slight and the CO is satisfied that they have been satisfactorily performed and can be sufficiently tested without a full power trial, such trial may be dispensed with.

Any unsatisfactory conditions beyond the capacity of ship's force should be corrected by the naval shipyard. If necessary, machinery should be opened up and carefully inspected to determine the extent of any injury, defect, or maladjustment which may have appeared during the post repair trial.

A certain number of naval shipyard personnel—technicians, inspectors, and repairmen—accompany the ship on a post repair trial. The yard personnel witness the operation of machinery that has been overhauled by the yard. If a unit of machinery is not operating properly, the yard technicians will carefully inspect it and try to determine the cause of unsatisfactory operation.

FULL POWER AND ECONOMY TRIALS

Trials are necessary to test engineering readiness for war. Except while authorized to disable or partially disable, ships are expected to be able to conduct prescribed trials at any time. Ships normally should be allowed approximately a 2-week period after tender overhaul, and a 1-month period after shipyard overhaul, to permit final checks, tests, and adjustments of machinery before being called upon to conduct a competitive trial.

Trials are also held from time to time to determine machinery efficiency under service conditions, the extent of repairs necessary, the sufficiency of repairs, and the most economical rate of performance under various conditions of service.

Inspections and Tests Prior to Trials

The full power and the economy trials, as discussed in this chapter, are considered in the nature of competitive trials. It is assumed that the ship has been in full operational status for sufficient time to be in a good material condition and to have a well-trained crew.

Prior to the full power trial, inspections and tests of machinery and equipment should be made to ensure that no material item will interfere with the successful operation of the ship at full power. The extent of the inspections and the tests will largely depend upon the recent performance of the ship at high speeds, the material condition of the ship, and the time limits imposed by operational commitments.

Not later than one day before a trial, the engineer officer should report to the CO the condition of the machinery installation, stating whether or not it is in proper condition and fit to proceed with the trial, or wherein any part is, in his opinion, not in a safe and proper condition.

General Rules for Trials

During all full power trials, and during other machinery trials to which they may be applicable and consistent with the conditions imposed, the following general rules should be observed:

1. The speed of the engines should be gradually increased to the speed specified for the trial. Prior to commencing a full power trial, the

machinery should be thoroughly warmed up; this can be accomplished by operating at a high fractional power.

2. The machinery should be operated economically, and designed pressures, temperatures, and number of revolutions must not be exceeded.

3. The full power trial should not be conducted in SHALLOW WATER, which is conducive to excessive vibration, loss of speed, and overloading of the propulsion plant. Detailed information on the proper depth of water for your ship may be obtained from chapter 9080 of NAVSHIPS Technical Manual.

4. If it is desirable to continue a full power trial beyond the length originally specified, the observations should be continued until the trial is finished. The four hours, or any other predetermined time, of the trial should be continuous and without interruption. If a trial at constant rpm be discontinued for any reason, that trial should be considered unsatisfactory and a new start made. No major changes of the plant set-up or arrangement should be made during economy trials.

Underway Report Data

Reports of trials should include all the attending circumstances, especially draft forward, draft aft, mean draft, and corresponding displacement of the ship at the middle of the trial; the condition of the ship's bottom; the last time dry-docked; the average horsepower developed by the main engines; the consumption of fuel per hour, per mile, and per shaft horsepower on indicated horsepower of the main engines per hour; the average speed of the ship through the water; and the average revolutions of the propelling engines. The methods by which the speed and shaft horsepower were determined should also be described.

This report should also include a tabulation of gage and thermometer readings of the machinery in use, and revolutions or strokes of pertinent auxiliaries. The auxiliaries in use during the trial should be stated. The report should state whether the machinery is in a satisfactory condition. If its condition is found to be unsatisfactory, all deficiencies should be fully described and recommendations made for correcting them.

Trial Requirements

Trial requirements for each ship, covering the revolutions per minute for full power at various displacements and injection temperatures, are furnished to commanders and units concerned, by the Chief of Naval Operations (Operations Readiness Division). The rpm for 15, 20, and 25 knots is also furnished for the appropriate ships.

Full power trials are of 4 hours duration, as far as the report data are concerned. The usual procedure is to operate the ship at full power for a sufficient length of time until all readings are constant, before starting the official 4-hour trial period. Economy trials are of 6 hours duration, a different speed being run at each time a trial is made.

Trials once scheduled should be run unless prevented by such circumstances as:

1. Weather conditions which might cause damage to the ship.

2. Material trouble which forces the ship to discontinue the trial, or which might cause damage to the machinery if the trial were continued.

3. Any situation such that running or completing the trial would endanger human life.

If a trial performance is UNSATISFACTORY, the ship concerned will normally be required to hold a retrial of such character as the type commander may consider appropriate to demonstrate satisfactory engineering readiness.

The fact that a ship failed to make the required rpm for any hour during the trial, and the amount by which it failed, should be noted in the trial report.

Observation of Trials

When full power trials are scheduled, observing parties should be appointed from another ship whenever practicable. When a ship is scheduled to conduct a trial while proceeding independently between ports, or under other conditions where it is considered impractical to provide observers from another ship, the ship under trial may be directed to appoint the observers. For economy trials, observers may be appointed from the ship under trial.

The number of personnel assigned to the observing party will vary according to size and type of ship. The duties of the observing party are usually as follows:

1. The Chief Observer will organize, instruct, and station the observing party. He checks the ship's draft, either at the beginning of the trial or before leaving port; supervises the performance of the engineroom observers; checks the taking of counter readings, renders all decisions in accordance with current directives' and checks and signs the trial report.

2. The Assistant Chief Observer assists the Chief Observer as directed; supervises the performance of the observers; checks the taking of fuel oil soundings and meter readings; and makes out the trial report.

3. Assistant observers take fuel soundings and meter readings, counter readings, the ship's draft, and other data as may be required for the trial report.

The following items should be accomplished or considered before starting the trial:

1. When requested by the observing party, the ship under trial should provide or designate a suitable signaling system so that fuel soundings and the readings of counters and meters may be taken simultaneously.

2. The ship under trial should furnish the Chief Observer with a written statement of the date of last undocking, and the authorized and actual settings of all main machinery safety devices and dates when last tested. The ship should have its draft, trim, and loading conform to trial requirements. In case a least draft is not specified, the liquid loading should equal at least 75 percent of the full load capacity.

3. The Chief Observer should determine draft and trim before and after the trial. He should verify the amount of fuel on board and correct this amount to the time of beginning the trial. He should determine the rpm required for the full power trial, at the displacement and injection temperature existing at the start of the trial

4. The observing party should detect and promptly correct any errors in recording data, since it is important that the required data be correct within the limits of accuracy of the shipboard instruments.

5. The Chief Observer should require members of the observing party to detect any violation of trial instructions, of instructions in NAVSHIPS Technical Manual, or of good engineering practice. The Chief Observer should verify any such report and then inform the commanding officer of the ship under trial. He should also include in the trial report a detailed account of any violation.

Manner of Conducting Trials

Some of the requirements in regards to the manner of conducting full power and economy trials are as follows:

1. Unless otherwise ordered, a full power trial may be started at any time on the date set.

2. The trial should be divided into hourly intervals, but readings should be taken and recorded every half hour. Data is submitted as hourly readings in the trial report.

3. Fuel expenditures for each hourly interval of the trial should be determined by the most accurate means practicable, preferably by meter readings corrected for meter error and verified by soundings.

4. The appropriate material condition of the ship should be set during the different trials.

5. During all trials the usual "housekeeping" and auxiliary loads should be maintained and the minimum services provided should include normal operation of the distilling plant, air compressor, laundry, galley, ventilation systems, elevators (if installed), and generators for light and power under load conditions similar to those required for normal operations at similar speeds under the prescribed material condition.

6. All ships fitted with indicators, torsionmeters, and other devices for measuring shaft or indicated horsepower should make at least two observations during the full power trial to determine the power being developed.

7. The Chief Observer should state in his report of the trial whether all rules for the trial have been complied with.

Some Hints in Regard to Full Power Trials

There are special forms used for full power and economy trial reports. Since illustrations of these forms are not given in this training manual, it is advisable to obtain copies of these report forms from your log room, to get some idea of the data and readings that will be required for full power and economy trials.

Trial forms, and such items as tachometers, stop watches, and flashlights, should be available to the observing party and to the personnel who take readings. Any gages or thermometers which are considered doubtful or defective should be replaced before trials are held. A quartermaster must check and adjust all clocks in the engineering spaces and on the bridge before any trials are held.

It is common procedure of many commanding officers, when making full power trials, to bring the ship up to a speed of one or more knots below the trial run speed of the ship. Then the control of the speed (except in cases of emergency nature) of the ship is turned over to the engineer officer. The control engineroom, under the supervision of the engineer officer, will bring the speed up slowly depending upon the conditions of the plant until the specified speed has been reached. In view of the fact that for most ships the designed boiler power is the first factor that establishes the maximum speed that the ship can attain, it is a good policy to check boiler steaming conditions before ringing up additional turns. The boilers should not be loaded down faster than they are capable of taking care of the increased load. The steam pressure and temperature should be kept at full value for the appropriate steaming condition. In other words, the turbines must not get ahead of the boilers. The boilers should be the controlling factor and should be kept ahead of the turbines. If the turbines are allowed to get ahead of the boilers, the main steam pressure and temperature will drop below normal values for that particular steaming condition, or speed of the ship. Then, in order to make up this loss in steam pressure and temperature and to meet additional increases of speed that may be rung up, the boilers must be fired at an extremely high rate. In some ships, this firing rate may exceed the full load rating of the boiler and approach the maximum 120 percent overload capacity rating of the boiler. As far as the engineering plant is concerned, the primary purpose of the acceleration curve or table is to prevent the overloading of boilers. The use of the acceleration curve is of particular importance when accelerating near full speed and full power.

CHAPTER 15

SHIP REPAIR

Ships can operate only a certain length of time without repairs. To keep a ship in prime condition, constant attention should be given to material upkeep and appropriate intervals of time must be allotted for general overhaul and repair.

Even when regular preventive maintenance procedures are carefully followed, accidents and derangements may necessitate emergency repair work. Defects and deficiencies which can be corrected by ship's force should be dealt with as soon as possible. When repairs are beyond the capacity of ship's force to accomplish, aid must be obtained from a repair activity afloat or ashore.

Repair activities afloat consist of repair ships and tenders; repair activities ashore consist of naval shipyards, private shipyards under contract with the Navy, and naval ship repair facilities (usually located outside the continental limits of the United States). The chapter discusses repair, alteration, and upkeep procedures for naval ships by forces afloat and by shore-based repair activities; it does not include information on the use of allowance lists and other sources for determining the repair parts, tools, and supplies carried on board, nor does it include information on the procedures for obtaining replacement parts and supplies. Such information is given in *Military Requirements for PO 3 & 2*, NAVEDTRA 10056-C, and in *Military Requirements for PO 1 & C*, NAVEDTRA 10057-C.

REPAIRS AND ALTERATIONS

Corrective maintenance to ships may be divided into the general categories of (1) repairs, (2) alterations, and (3) alterations equivalent to repairs.

A REPAIR is defined as the work necessary to restore a ship or ship system component condition without change in design, location, or relationship of parts. Repairs may be accomplished by ship's force by repair ships and tenders, or by naval shipyards or other shore-based activities.

An alteration to a naval ship is any change in the hull, machinery, equipment, or fittings that involves a change in design, materials, number, location, or relationship of the component parts of an assembly regardless of whether it is undertaken separately from, incidental to, or in conjunction with, repairs. Requests for alterations may originate with the Naval Sea Systems Command, the forces afloat, or the Chief of Naval Operations (CNO).

A prime responsibility of the Naval Sea Systems Command for ship maintenance is that of administering alterations under its technical cognizance. In its day-to-day relations with the forces afloat, the naval shipyards, private industry, and research centers, the Naval Sea Systems Command keeps informed of technical developments. In striving to maintain the ships of the fleet in as efficient and modern a state as possible, the Naval Sea Systems Command may determine that a particular ship or class of ships should be altered to encompass desired improvements. These alterations may be changes to the hull, such as changes to bulkheads that will strengthen them or changes to deck arrangements that will provide space for installation of machinery; changes to machinery or the substitution of newer and more efficient machinery; changes to equipment, such as the replacement of an item with a more efficient type; or changes in design, such as the installation of a paint mixing and issue room.

When the commanding officer of a ship considers an alteration necessary for the satisfactory performance of his ship, he addresses a request for the alteration to the Naval Sea Systems Command via the administrative chain of command. Copies of the request are sent to all ships of the type within the appropriate fleet for comments as to applicability.

Another source of alterations is the reports of the Board of Inspection and Survey. Upon completion of each material inspection, the Board, in its report of the general condition of the ship and its suitability for further naval service, furnishes a list of repairs, and alterations, which, in its opinion, should be made. Alterations recommended by the Board of Inspection and Survey normally are not acted upon by the Naval Sea Systems Command until after the receipt of appropriate requests from the commanding officers of the ships inspected and the recommendations of the type commanders.

Alteration requests addressed to the Naval Sea Systems Command are endorsed by the type commanders (or other administrative commanders, as appropriate), with their recommendations as to approval, classification, and applicability to other ships of the type. Copies of the basic request and endorsements are forwarded to other type commanders concerned, who are also requested to comment on them for the information of the Naval Sea Systems Command.

Alterations involving material under the technical cognizance of the Naval Sea Systems Command are known as SHIPALTS. SHIPALTS can be approved by the Naval Sea Systems Command when the alterations do not affect military characteristics of the ships concerned. A SHIPALT that affects military characteristics requires approval by CNO. Any SHIPALT that requires the approval of CNO is called a NAVALT. Alterations under the technical cognizance of the Naval Sea System Command, regardless of whether or not they affect the military characteristics of ships, are known as SHIPALTS. Thus an alteration might be only a SHIPALT or it might be both a SHIPALT and a NAVALT.

When the Naval Sea Systems Command determines that a SHIPALT affects the military characterics of the ship, the alteration is forwarded to CNO. In approving NAVALTS, CNO also establishes the relative priority for their accomplishment. The NAVALTS are then recorded in the Ship Improvement Guide (SIG) for overall and long-range planning purposes and in the Material Improvement Plan. NAVALTS are classified by CNO as follows:

Priority 1—Mandatory for national security.
Priority 2—Essential for combat readiness.
Priority 3—Desirable for naval efficiency.

An ordinary SHIPALT (a SHIPALT that does not affect military characteristics) may be approved by the Naval Sea Systems Command after all factors have been considered, including the effect of the change on weight stability, space, and power. Following approval, the relative priority of accomplishment of the SHIPALT is established. Priorities assigned to ordinary SHIPALTS are:

Priority A—Mandatory.
Priority B—Essential.
Priority C—Desirable.

SHIPALTS not affecting military characteristics of a ship are those SHIPALTS that, in general, concern matters of safety, efficiency, and economy of operation or maintenance. Annually, the Naval Sea Systems Command compiles and issues a ship-type priority list of all ordinary SHIPALTS. The SHIPALTS are grouped so that those of approximately equal importance fall into the same priority groups regardless of the type ship. The SHIPALT priority lists are revised and reissued as necessary during the year.

Approval of a SHIPALT is usually evidenced by its issuance, or by a letter, to be followed by issuance of the SHIPALT, to the activities immediately concerned. Type commanders periodically review approved SHIPALTS and initiate action to CNO or the Naval Sea Systems Command (as appropriate) for cancellation of those no longer considered necessary.

A SHIPALT may not be accomplished in any ship until its accomplishment has been specifically authorized by the Naval Sea Systems Command. The Naval Sea Systems Command reviews the outstanding SHIPALTS for each ship in advance of regular overhauls. SHIPALTS to be accomplished are selected from the Material Improvement Plan and the priority lists, with due consideration being given to relative priorities and to current budgetary or fiscal limitations. The SHIPALTS to be accomplished are authorized by letters issued not less than 180 days prior to the scheduled commencement of the ship's overhaul.

After study of a request for an alteration, the Naval Sea Systems Command may determine that the alteration is an alteration equivalent to a repair. An alteration that has been designated an alteration equivalent to a repair is forwarded to the appropriate type commander for accomplishment as a repair.

An alteration is considered to be an alteration equivalent to a repair if it meets one or more of the following conditions:

1. The substitution, without other change in design, of materials which have previously been approved for similar use and which are available from standard stock.
2. The replacement of wornout or damaged parts, assemblies, or equipments requiring renewal by those of later and more efficient design previously approved.
3. The strengthening of parts that require repair or replacement in order to improve reliability of the parts and of the unit, provided no other change in design is involved.
4. Minor modifications which involve no significant changes in design or functioning of equipment but which are considered essential to prevent recurrence of unsatisfactory conditions.

SHIP AVAILABILITIES

As it applies to work on naval ships, an AVAILABILITY is the period of time assigned a ship by competent authority for the accomplishment of repairs, alterations, and alterations equivalent to repairs at a repair activity.

During certain availabilities, a ship may be incapable of engaging in fleet operations and the operating schedule is adjusted accordingly. Only the authority granting the availability can alter or extend the period of the availability; however, a repair activity may request that the ship's availability be extended so that work can be completed or it may recommend a completion date to the authority granting the availability.

SHIP'S FORCE MAINTENANCE AND REPAIRS

Each ship should insofar as practicable, be self-sustaining with regard to normal repairs. Each ship should be well supplied with materials, repair parts, and tools and equipment so that much of its own repair work can be accomplished by ship's force. Repairs should be undertaken under the supervision of the most competent and experienced personnel. Personnel not familiar with specific repairs and tests should be instructed to take advantage of ship or repair ship availabilities or tender assignments to observe how such work is undertaken.

The purpose of preventive maintenance is to maintain satisfactory material condition and ensure that the equipment or machinery is always ready for service. A regular schedule of cleaning, inspections, operations, and tests is required to ensure trouble-free operation and the detection of incipient faults before they become catastrophic ones.

Most routine inspections and tests are performed by ship's force. Some of these inspections and tests are quite simple; others require planning so that they can be undertaken during upkeep or overhaul periods. Shipyard and repair ship assistance should not be requested unless the test or inspection is actually beyond ship's force capacity.

An interdepartment routine request for work requiring assistance by another shipboard department is referred to as a ship's memorandum work request. Such a form enforces proper channeling of a work request between departments, and permits the setting up of priorities of available manpower and facilities. The work request memorandum is a form which is made up by the ship; however, some ships use the Repair Record, or the repair work request for this purpose.

REPAIR SHIP/TENDER REPAIRS

Ships are scheduled for a regular tender availability or an upkeep period alongside repair ships or tenders at certain intervals of time. These time intervals vary with different types of ships. The availability periods are usually planned far in advance and depend upon the quarterly activity schedule of the ship concerned.

When a ship receives its activity schedule, or is otherwise notified, it can begin to prepare the necessary paperwork in advance of the scheduled availability period. The Maintenance Deferred Action Sheet is used as a basis for advance preparation of a work request.

The work requests, with the required number of copies, are sent with a forwarding letter to the type commander. The staff officer handling material and maintenance screens the work requests. Most of the ship's availability work list items are approved and authorized. Also, the ship may have to furnish more detailed information on certain work requests. The amount of corrective action taken by the reviewing staff officer will depend upon how well the work requests are written and the extent to which they follow established policies and procedures. Upon the completion of this screening, the ship's work requests are forwarded to the repair ship or tender. This is done well in advance of the assigned period of availability so that the repair department personnel can schedule the work and make any necessary preparations.

ARRIVAL CONFERENCE

When a ship comes alongside for a regular tender availability or an upkeep period, an arrival repair conference is usually held immediately. The conference is attended by representatives of the ship, of the repair department, and (usually) of the type commander. The relative needs of the ship and the urgency of each job are discussed. The arrival repair conference serves to clear up uncertainties for repair department personnel who have received and studied the work requests.

Arrangements are also made for the repair ship to provide the primary services of steam and electricity in sufficient quantity to take care of heating and lighting requirements and to provide limited power for ships alongside. In addition to these services, the repair ship may over communication watches. Fresh water and fuel requirements are usually supplied from barges.

WORK REQUESTS AND JOB ORDERS

Although the terms "work request" and "job order" are sometimes used interchangeably, this is not technically correct because the two terms actually have slightly different meanings. Work requests are made up by the ship and are forwarded through proper channels to the repair activity. When the work request has been approved by the repair activity, it is issued as a job order.

As soon as the work requests have been approved at the arrival conference, the jobs that require delivery to the tender should be started. Starting these repair jobs early is very important in getting all necessary jobs completed. Equipment that is not needed for the operation of the ship may be disassembled in advance so that the defective parts can be delivered to the tender as soon as the work requests have been approved.

All material delivered to the tender must be properly tagged and identified. The information on each tag should include the number and name of the ship; the department, division, or space; and the job order number, Additional information should be included if necessary. Reference material such as blueprints and manufacturer's technical manuals should be identified with the ship's name and number.

Ship-to-Shop Jobs

Many repair jobs are designated by the ship or approved by the repair activity as "ship-to-shop" jobs. In a job of this type, ship's force does a large part of the repair work. For example, the repair or renewal of a damaged pump shaft might well be written up as a ship-to-shop job. The pump is disassembled and the shaft is removed by ship's force; the shaft and any necessary blueprints are delivered to the machine shop of the repair activity. The machine shop supervisor checks the job and gives an approximate date of completion. When the shaft has been repaired, or when a new one has been made, it is picked up and brought back to the ship by ship's force. The pump is reassembled, inspected, and tested by ship's force to ascertain that the unit is satisfactory.

Repair jobs on portable equipment such as small gages and valves are almost always written up as ship-to shop jobs.

Checking Progress of Tender Repair Jobs

The petty officer in charge should know at all times the status of repair work (including ship's force repair work) being done for his space or equipment.

Tender repairs that are being accomplished on your own ship can be checked by discussing them with the petty officer in charge of the repair detail. Checking on the progress of work in the shops on the tender requires planning and coordination between your ship and the tender. Personnel in the tender shops are busy with their repair work, so any method used to check on progress of work must be one which does not interfere with progress.

Some tenders and repair ships have a chief petty officer who acts as ship superintendent. His duties include:

1. Acting as liaison officer between the ships alongside and the tender in regard to repair department jobs.
2. Acting as a coordinator of shop work for assigned ships.
3. Reporting daily to a representative of the ship.
4. Maintaining a daily running progress report or chart which indicates the percentage of completion of each job; the availability of plans, manufacturers' technical manuals, samples, etc.; and the availability of materials required for each job.
5. Notifying the ship when it is time to pick up completed work from the tender.
6. Notifying ship's personnel when it is necessary for them to witness tests needed because work has been performed on machinery, compartments, tanks, etc.
7. Obtaining signatures from officers if job orders are cancelled or changed.

If the tender provides a ship superintendent, it is obviously quite easy for ship's personnel to ·k on the progress of the work. If the services of a ship superintendent are not provided, the ship alongside the tender should appoint a petty officer to perform similar duties for the division or department.

A progress chart should be kept for all work that is planned for accomplishment during the repair period. The chart should be kept up to date with respect to the status of each job. Keeping a close watch on the progress of the repair work will ensure that jobs, are not unnecessarily delayed, that jobs are not overlooked or forgotten, and that all work undertaken is satisfactorily completed at the end of the repair period.

NAVAL SHIPYARD REPAIRS

The primary purpose of a naval shipyard is to render services to the fleet in the form of efficient and economical construction, repair, alteration, overhaul, docking conversion, outfitting, and replenishment and to perform related special manufacturing when required. Naval shipyards perform many other functions, including research and design, which are not discussed here.

Naval shipyards are designated as home yards and as planning yards. A home yard is the shipyard to which a particular ship is usually assigned for the accomplishment of a regular overhaul. A planning yard is a shipyard which has been designated by Naval Sea Systems Command as the yard which undertakes the design work for the type ship allocated to it.

WORK REQUESTS

The procedures for submitting shipyard work requests prior to a regular overhaul are laid down, in the *Maintenance and Material Management (3-M) Manual.*

Type commanders require that work requests to be accomplished during a repair period (regular or interim) be submitted (for their inspection, screening, and approval) in sufficient time to allow completion of the type commander's action and arrival of the work requests at the shipyard in advance of commencement of the overhaul; this is necessary in order to permit successful preliminary planning by the shipyard.

Each work request is submitted on the standard work request form. All work requests are screened and assigned a priority for accomplishment at a conference of the heads of department, the executive officer, and the commanding officer. A work list containing brief statements of the work to be accomplished, arranged in the ship's integrated priority sequence, is prepared and submitted along with the work requests to the type commander for his screening action.

ALTERATION REQUESTS

The list of authorized alterations that are to be accomplished at a routine naval shipyard overhaul is prepared by NAVSEA. NAVSEA usually provides the type commander with a priority list of the alterations to be accomplished on the ship scheduled for a regular overhaul approximately 180 days prior to the overhaul. The type commander may submit to NAVSEA recommended changes in this prospective priority list. The type commander usually requests recommendations from the ship concerned in regard to SHIPALTS that should be completed during the shipyard overhaul period. Late requests for alteration authorization are discouraged.

For an authorization of a late alteration request to be considered for approval, it must first be determined that the alteration requested is:

1. Strictly confined to items of vital operational requirements which involve late and significant technological developments.
2. Feasible of accomplishment from the standpoint of plan development and special material availability within the scheduled overhaul availability of the ship.
3. Acceptable to the overhauling shipyard.
4. Acceptable from the standpoint of availability of funds.

Approximately 90 days in advance of the ship's arrival, NAVSEA will forward to the shipyard, to the type commander, and to the ship a list of approved alterations (90 day material status letter) in the priority applicable to the individual ship. Any changes in the scope of work authorized in the 180-day letter will be reflected in this letter.

SHIPALTS marked for accomplishment by forces afloat are not, as a rule, undertaken by naval shipyards.

Naval Shipyard Arrival Conference

When the ship arrives at the shipyard for a routine overhaul, an arrival conference is held. The conference is supervised usually by the planning officer of the shipyard and attended by representatives from the ship, the type commander, and the naval shipyard planning department. The ship's work requests and the individual item costs estimated by the shipyard planning department are reviewed. When necessary, the details of the repair items are discussed, and the work to be done is decided upon.

The limitations of the funds made available by the type commander determine to a great extent the amount of repairs that will be accomplished during a naval shipyard repair period. The estimated cost of each repair job, when approved at the conference, is added up to give the total cost. When the total cost reaches approximately the amount of funds appropriated, or the cutoff point, the shipyard will not accept additional repair requests. Under this condition, when there are several additional important jobs that should be accomplished, the type commander must either furnish more funds or rearrange the individual items in question and revise the priority list accordingly.

Establishing the cutoff point enables the shipyard to make certain that the most important repairs and alterations are accomplished during the availability period. This does not necessarily imply that other items with less urgent priority will be undertaken and accomplished before the end of the overhaul period. After the ship has been placed in drydock, for example, it may be found that anticipated repairs to the shafting and propeller will not be required, and the funds reserved for this work can be used to finance other items. Sometimes a job may be seriously underestimated because of conditions that were not apparent until the job was well underway. If funds were not originally provided to cover the cost of the work, the necessary funds may now be provided by deferring other approved items of less relative importance.

Also established at the arrival conference are tentative dates for drydocking, the operation of the propulsion machinery and associated auxiliary equipment, and dock and sea trials.

When agreement has been reached at the arrival conference on the items of work to be undertaken, the planning department issues job orders authorizing the work to be performed by the production shops. Each job order clearly defines the scope of the work, includes complete specifications, and identifies the necessary plans. Job orders are not issued for all work at the same time. The first to be issued are for those jobs requiring practically the entire availability period. The other orders are issued as soon as possible thereafter. If design plans are required for the accomplishment of any specific item, the issue date of the job order is coordinated with the planned completion date. In any case, job orders for all items approved at the arrival conference are usually issued during the first third of the overhaul period.

The method of numbering job orders differs somewhat in the several naval shipyards. However, the numbering systems are all for the purpose of identifying a particular item of work by a job order number. In addition to the naval shipyard job order number, the ship's work request or work item number is entered on the job order sheets for identification purposes.

Checking on Progress of Work

During a routine shipyard overhaul the ship must submit shipyard progress reports in accordance with the type commander's instructions. Supervisory personnel of the ship must therefore keep an accurate check on the progress of all work (including ship's force work) at all times. Standard progress charts are available for recording and reporting progress. As a rule, one progress chart is used to record shipyard repairs, another to record alterations, and another to record ship's force work. Copies of the progress charts should be posted outside the log room and kept up to date by assigned ship's personnel.

The shipyard commander holds frequent (usually weekly) conferences with the commanding officer of the ship to review progress. The ship superintendent and other key shipyard personnel also attend these conferences.

In checking on the progress of work, it is of course necessary to know what repair work is planned for accomplishment during the overhaul. This information can be obtained from the job orders issued by the planning department of the yard. The ship receives three or more copies of the job orders. A complete set of job orders is usually kept on file in the log room; a set of the job orders that apply to your division is usually kept by your division officer. Always check the details of the job orders before you start checking on the progress of a repair job.

OBTAINING ADDITIONAL REPAIR JOBS

It may be necessary to prepare supplementary work requests to include items arising after the submission of the original work requests. Additional repairs may be required because of voyage casualties or because of conditions discovered during shipyard tests and inspections. The supplementary work requests must be submitted in accordance with the same procedure used for submitting the original work requests, and the supplementary items must be dovetailed into the ship's priority index.

Supplementary work requests should be made out immediately, as soon as the need becomes evident, and submitted to the yard as soon as possible after they have been prepared.

INSPECTION DUTIES OF SHIP'S FORCE

The inspection of work being done by a repair activity for a ship is the responsibility of both the repair activity and the ship. The repair activity should require such inspections to be made as will ensure the proper execution of the work and adherence to prescribed specifications and methods. Ship's personnel should make such inspections as may be necessary to determine if the work is satisfactory, both during its progress and when completed. The petty officer in charge should schedule his work in such a manner that he will have time to inspect and check the progress of naval shipyard work going on in his space or being performed on equipment for which he has the responsibility of maintenance and upkeep. A check should be made to see that all required tests are made by the shipyard before the job is considered complete. The navel shipyard job order will list any tests that have to be made by yard personnel.

In case any unsatisfactory work is being performed by shipyard personnel, you should follow the instructions put out by your engineer officer. Talking things over in a friendly manner with the workmen will usually solve your problems; if this is not successful, notify your division officer or the engineer officer, who can take up problems of unsatisfactory work with the ship superintendent. In exceptional cases the CO of your ship can take necessary action in accordance with Navy Regulations.

On many ships the division officer or the engineer officer will check with you before he signs a job order as being completed. By a continuous inspection of shipyard work, and by checking off the jobs that have been satisfactorily completed, you can furnish the required information without unnecessary delays.

DRYDOCKING THE SHIP

The ship is drydocked each time it goes into a naval shipyard for a regular overhaul. Drydocking is usually scheduled as early as possible in the overhaul period, since it is difficult to tell in advance just how much drydock work will be required. Scheduling the drydocking for early in the overhaul permits the accomplishment of all necessary drydock work without interfering with work which must be done later and without interfering with machinery trials, strength tests of structural work, and so forth. As soon as all drydock work has been completed, the ship is removed from drydock.

Before the ship goes into drydock, ship's personnel must have detailed information on the sea valves. When preparing to drydock the ship, the engineer officer is required to furnish the shipyard with a sea valve checkoff list indicating the size, location, and function of each sea valve. He must also furnish the yard with the ship's docking plan and, if the ship was last drydocked in a different shipyard, the last docking report. The shipyard maintains file copies of docking plans for each ship which it is expected to drydock. However, it is necessary to check these plans against the ship's copy to make any corrections reflecting work done elsewhere and to determine the last docking position used.

A ship entering drydock should be without list and without excessive trim. Trim in excess of 1 foot per 100 feet of length is sufficient to make the docking operation hazardous. If practicable, the trim should be brought below this limit before any attempt is made to drydock the ship.

While the ship is in drydock, no fuel oil, water, or other weight should be shifted, added or removed, except as specifically authorized by the docking officer. Water tanks and oil tanks should be either completely full or completely empty, if practicable. When permission is given by the shipyard to shift weight, ship's force must keep accurate records of the amount of weight shifted, the location from which it is shifted, and its new location.

The propellers must not be turned without permission of the docking officer after the ship enters the dock. No fuel oil or other flammable liquid should be drained or pumped into the dock. If the need arises, the shipyard will provide special containers for the disposal of these liquids. During freezing weather, all valves, pipes, and fittings attached to the hull should be drained to prevent freezing and consequent cracking.

Whenever a ship is drydocked, propellers, shaft tubes, outboard portions of the shafting, couplings, bearings, and all sea valves must be examined and the results of the examination must be entered in the engineering log.

Examination of each sea valve should include determination of the condition of the yoke, yoke rods, valve stem, securing bolts, and all internal parts of the valve. At least two of the bolts holding outboard valves to sea stools should be removed from each valve for inspection, and the remaining bolts should be sounded with a hammer. If defects are found in any bolt, all the other bolts for the valve should be removed for inspection. Whenever all bolts are removed, the gasket should be replaced. All repairs required to place the sea valves in good condition should be made while the ship is still in drydock.

While the ship is in drydock, ship's force and shipyard personnel may have occasion to work on sea valves. All openings in the hull must be blank-flanged at the end of working hours; ship's force and shipyard personnel are each responsible for closing the openings which they make in the hull. At the end of each working day, status of all sea valves must be reported to the engineer officer entered in the engineering log.

Before the drydock is flooded, all sea valves must be carefully inspected to be sure they are properly secured. The results of this inspection should be reported to the engineer officer and entered in the engineering log.

While the drydock is being flooded, there must be continuous inspection of all sea valves until the ship is afloat and all valves are under a normal head of water. Any unsatisfactory condition must be reported at once to the engineer officer so that the docking officer can be notified. A report of leakage must be made in sufficient time so that the docking officer can stop flooding, if necessary, before the ship lifts from the supporting blocks.

Shortly after the undocking of a ship, the shipyard submits the docking report to NAVSEA with copies to the commanding officer and the type commander. The docking report includes the name and class of ship; the place and date of docking and undocking; the number of days underway, not underway, and waterborne since the last docking; the formula for the paint used and the extent of bottom painting; the shaft and rudder clearances; the docking position used; and details of all other work performed.

DOCK TRIAL

A dock trial is always held after major repairs to propulsion machinery have been made by a naval shipyard. A dock trial is usually held at the completion of a routine naval shipyard overhaul.

At least one day prior to the dock trial, all auxiliary machinery should be tested to prevent delay or interference with the testing of the main engines and associated equipment.

The actual tests of propulsion machinery are made by the ship's engineering personnel, under direction of the engineer officer. The ship is secured to the pier during this trial. The propulsion machinery and equipment must be tested sufficiently to ensure that it has been properly repaired and is in satisfactory operating condition. Any defect, deficiency, or maladjustment must be corrected either by ship's force or by shipyard personnel. The dock trial is repeated as often as necessary until conditions are satisfactory.

CPO AND PO1 RESPONSIBILITIES

Much of the information just given on Navy repair procedures is of less direct concern to you than it is to ship's officers type commanders, fleet commanders, the Naval Sea Systems Command, and shipyard personnel. You need some general knowledge of these procedures so that you can provide maximum assistance in the overall job of getting the work done. However, such general knowledge is not enough by itself. You must also know what is expected of you as a CPO or PO1 in the engineering department, when your ship goes alongside a tender or repair ship or enters a shipyard for overhaul. Also, if you are assigned to a tender or repair ship, you must know just what is expected of you when other ships come alongside.

If you are on a ship that is coming alongside a tender or repair ship or entering a shipyard, one of your first and most important duties is furnishing information. No one should be in a better position than you to know exactly what is wrong with the equipment or machinery for which you are responsible. The accuracy and completeness of the information you give will have a definite effect on the decisions made by higher authority concerning the repair work. For example, a type commander is not in a position to decide offhand whether reconditioning a valve is more urgent than refacing a flange, or whether repairing a pump is more urgent than patching a bulkhead. Decisions like these can only be made on the basis of full and accurate information. Since literally hundreds of decisions may be required when a ship goes in for overhaul, the importance of furnishing accurate and complete information on all needed repairs must be thoroughly understood by all petty officers.

Keeping records and reports up to date and accurately filled out is the best way to make sure that all information on repairs and alterations will be available when it is needed. You have a definite responsibility for providing information for the required records and reports.

On ship-to-shop jobs, you will probably be required to supervise the dismantling and removal of pumps, gages, valves, electric motors, and other relatively small items from your spaces. Remember that all parts must be tagged and that the identification must be accurate and complete.

When repair personnel come aboard your ship to make repairs, your first responsibility is to make sure that everything is ready so that the work can proceed without delay. After the repair personnel are on board, you will have to stand by to provide information and at times to assist with the work. If staging is required, it is usually furnished by the deck force of your own ship; again, however, you will be expected to assist when the work is being done in your own spaces. The deck force can erect the staging, but you should keep a close watch to see that it will be suitable for the particular job that must be done.

Fire watches are usually furnished by the ship coming alongside a tender or repair ship. As a CPO or PO1, you may be required to set fire watches and to assign men to the watches.

As a CPO or PO1 on a repair ship or tender, you will have somewhat different responsibilities. If you are in charge of a shop, you will be responsible for seeing that the required materials are available, that all tools and equipment are in good working order, and that the shop work is scheduled according to the established priorities. You will have to keep checking on your men to see that the work moves along according to schedule. If bottlenecks develop, you will have to find a way out of the difficulty.

Repair personnel on the repair ship or tender are usually responsible for furnishing all necessary papers in connection with welding or cutting in dangerous or poorly ventilated spaces. As a rule, certifications that a space is safe for entering or safe for hot work must be signed by the gas-free engineer on the repair ship or tender AND by the gas-free engineer on the ship alongside. One copy of the appropriate certification must be posted at the place where the hot work is to be done.

Repair personnel on the repair ship or tender are responsible for testing all items which they fabricate (valves, piping section, etc.) to make sure that all requirements are met. If a job order is written up in such a way that you are required to reinstall the equipment, you will be responsible for testing it after installation and for seeing that it is operating correctly.

A general rule of responsibility is that repair personnel of tenders, repair ships, and shipyards are responsible for an item or a piece of work until the job order is signed off; after that, the responsibility is with the ship. However, this general rule of responsibility may be modified by particular circumstances.

Whether you are on a repair ship or tender or on the ship coming alongside, you will have a great deal of responsibility for the safety of personnel. Repair work frequently requires the observance of additional precautions, over and above those that must normally be observed aboard ship. The hazards may be particularly great if your men are unfamiliar with the equipment being used by repair personnel.

All repair personnel must share responsibility for seeing that repairs and alterations do not result in unauthorized changes in weight, movement, or stability of the ship. Over the course of years, some naval ships have suffered such weight changes—and particularly such weight additions—that their powers of survival in an emergency are seriously impaired. Although the addition of a small amount of weight here or there or the shifting of a small amount of weight from one place to another may appear to be trivial, the cumulative effect can be extremely serious. Weight changes generally happen a little at a time. The danger is particularly great because the weight changes, being small and unsystematic, tend to be unnoticed and therefore uncompensated. Haphazard weight changes that endanger the safety of the ship can only be controlled if all repair personnel share the responsibility for not allowing unauthorized alterations or weight changes.

CHAPTER 16

RECORDS AND REPORTS

Engineering records and reports for the administration, maintenance, and repair of naval ships are prescribed by directives from authorities such as the type commander, NAVSEA and CNO. These records and reports must be accurate and adequate, and must be kept up to date in accordance with current instructions.

As an MM3 and MM2, you have been primarily concerned with operating logs and similar records. As an MM1 and MMC, you will have new supervisory duties which will require that you have a greater knowledge of engineering paperwork and the associated administrative procedures. Supervisory duties and responsibilities require a knowledge of engineering records as well as of such items as inspections administrative procedures, training, preventive maintenance, and repair procedures.

Information on some of the most common engineering records and reports is given in this chapter. These standard forms are for issue to forces afloat and can be obtained as indicated in the Navy Stock List of Forms and Publications, NAVSUP 2002. The forms are revised as conditions warrant; personnel ordering forms must be sure that current forms are obtained. When complementary forms are necessary for local use, make certain that an existing standard form will not serve the purpose before having complementary forms prepared and printed.

LEGAL ENGINEERING RECORDS

The Engineering Log and the Engineer's Bell Book are the only legal records compiled by the engineering department. The Engineering Log is a midnight-to-midnight record of the ship's engineering department. The Engineer's Bell Book is a legal record of any order regarding change in the movement of the propellers.

ENGINEERING LOG

The Engineering Log, NAVSHIPS 3120/2 (fig. 16-1) together with the Log continuation Sheet, is a complete daily record, by watches, of important events and data pertaining to the engineering department and the operation of the ship's propulsion plant. The log must show the average hourly rpm (to the nearest tenth) for all shafts; the speed in knots; the total engine miles steamed for the day; all major speed changes; draft and displacement upon getting underway and anchoring; fuel, water, and lubricating oil on hand, received, and expended; the disposition of the engines, boilers, and principal auxiliaries, and any changes in their disposition; any injuries to engineering department personnel; any casualties to engineering department machinery, equipment, or material; and such other matters as may be specified by competent authority.

Entries in the Engineering Log must be made in accordance with instructions given (1) on the log sheet (NAVSHIPS 3120/2), (2) in chapter 9004 of NAVSHIPS Technical Manual, and (3) in directives issued by the type commander. Each entry must be a complete statement and employ standard phraseology. The type commander's directives contain other specific requirements pertaining to the remarks section of Engineering Logs for ships of the type; the engineer officer must ensure compliance with these directives.

The original Engineering Log, prepared neatly and legibly in ink or pencil, is the legal record. The remarks should be prepared—and must be signed—by the engineering officer of the watch

ENGINEERING LOG - ALL SHIPS
NAVSHIPS 3120/2 (REV. 8-67) (FRONT)
(Formerly NAVSHIPS 117)

DAY ______ MONTH ______ 19 ______ PAGE ______

U. S. S.

AT OR ENROUTE FROM ______ TO ______

NOTES: * TO TENTHS, USE WHOLE NUMBERS FOR OTHER ITEMS
** ON GETTING UNDER WAY AND ANCHORING

BLANK SPACES IN HOURS FOR DATA WHEN CLOCKS ARE SET BACK
BEGIN NEW SERIES OF PAGE NUMBERS EACH CALENDAR YEAR

USE REVERSE SIDE FOR ADDITIONAL REMARKS

USE EXCEPTIONAL CARE TO WRITE THIS LOG LEGIBLY AND KEEP IT CLEAN

*TABLE 1		
ZONE TIME	AVG. RPM ALL SHFTS	SPD IN KNOTS
01		
02		
03		
04		
05		
06		
07		
08		
09		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

TABLE 2 - ENTRIES IN GALLONS

ITEM	FUEL OIL		WATER				LUBE OIL		
	HEAVY	DIESEL	POTABLE	FEED	PURE	OTHER	DIESEL	STEAM	OTHER
BROUGHT FWD AT 0000									
REC'D TODAY									
INCREASE BY INVENTORY									
DISTILLED TODAY	XXXX	XXXX					XX	XX	XX
TOTAL RECEIPTS									
EXPENDED BY USE									
EXPENDED BY INVENTORY									
TOTAL EXPENDED									
ON HAND AT 2400 TODAY									

TABLE 3

DRAFT / DISPLACEMENT	FORWARD	AFT	MEAN	TONS
	FT IN	FT IN	FT IN	
	FORWARD	AFT	MEAN	TONS
	FT IN	FT IN	FT IN	

MILES - 0000-2400 TOTAL DISTANCE THROUGH WATER FROM NAVIGATOR'S DATA NOT DISTANCE MADE GOOD

ENGINE MILES - 0000-2400 FROM TABLE 1 SUM OF HOURS TIMES ENGINE SPEEDS | DAYS OUT OF DOCK

INSTRUCTIONS

The Engineering Log may be written with pencil or pen as most convenient. The ORIGINAL writing is the LEGAL RECORD and must be preserved. It is not necessary to make a copy except when one or more pages are sent away from a ship in commission.

Table 1 and the REMARKS must be written at the time events occur. Other tables may be written before noon the following date.

REMARKS shall be written by "watches" underway and by "day's duty" at anchor. They shall be signed by the Engineer Officer of the Watch or Day before going off duty.

Remarks shall be a chronicle of important events. They shall include: first, boilers in use; second, engine combination in use; third, major speed changes, such as "one third," "standard," "full"; fourth, casualties to personnel or material within or under the cognizance of the engineer department; fifth, special entries required by Navy Regulations, Naval Ships Technical Manual, and Instructions and letters of the Naval Ship Systems Command.

ALTERATIONS OR ERASURES ARE NOT PERMITTED. NECESSARY CORRECTIONS SHALL BE MADE ONLY IN THE MANNER PRESCRIBED BY ART. 1046 NAVY REGULATIONS.

DISPOSITION

For disposal of this record see current records disposal instructions for vessels of the U. S. Navy.

REMARKS - USE REVERSE SIDE

TIME ZONE DESCRIPTION | CLOCKS SET BACK OR AHEAD ______ HRS ______ MINUTES AT ______

S/N 0105-601-0690

FOR OFFICIAL USE ONLY (WHEN FILLED IN)

98.162

Figure 16-1.—Engineering Log.

(underway) or the engineering department duty officer (in port). No erasures are permitted in the log. When a correction is deemed necessary, a single line is drawn through the original entry so that the entry remains legible and the correct entry is inserted in such a manner as to ensure clarity and legibility. Corrections, additions, or changes are made only by the person required to sign the log for the watch and are initialed by him on the margin of the page.

The engineer officer verifies the accuracy and completeness of all entries and signs the log daily. The commanding officer approves the log and signs it on the last calendar day of each month and on the date he relinquishes command. The engineer officer should require that the log sheets be submitted to him in sufficient time to allow him to check and sign them prior to noon of the first day following the date of the log sheet(s). Completed pages of the log, filed in a post-type binder, are numbered consecutively, beginning with the first day of each calendar year and going through the last day of the calendar year.

When the commanding officer (or engineer officer) directs a change or addition to the Engineering Log, the person concerned must comply unless he believes the proposed change or addition to be incorrect; in which event the commanding officer (or engineer officer) enters such remarks over his signature as he deems appropriate. After the log has been signed by the commanding officer, no change is permitted without his permission or direction.

ENGINEER'S BELL BOOK

The Engineer's Bell Book, NAVSHIPS 3120/1 is a record of all bells, signals, and other orders received by the throttleman regarding movement of the ship's propellers. Entries are made in the Bell Book by the throttleman (or an assistant) as soon as an order is received. Entries are usually made by an assistant when the ship is entering or leaving port, or engaging in any maneuver which is likely to involve numerous or rapid speed changes. This procedure allows the throttleman to devote his undivided attention to answering the signals.

The Bell Book is maintained in the following manner:

1. A separate bell sheet is used for each shaft each day, except where more than one shaft is controlled by the same throttle station, in which case the same bell sheet is used to record the orders for all shafts controlled by the station. All sheets for the same date are filed together as a single record.

2. The time of receipt of the order is recorded in column number 1.

3. The order received is recorded in column number 2. Minor speed changes (generally received via revolution telegraph) are recorded by entering the number of rpm ordered. Major speed changes (normally received via engine order telegraph) are recorded using the following symbols:

1/3 – ahead 1/3 speed
2/3 – ahead 2/3 speed
I – ahead standard speed
II – ahead full speed
III – ahead flank speed
Z – stop
B1/3 – back 1/3 speed
B2/3 – back 2/3 speed
BF – back full speed
BEM – back emergency speed

4. The number of revolutions corresponding to the major speed change ordered is entered in column 3. When the order received is recorded as rpm in column 2 (minor speed changes), no entry is made in column 3.

5. The shaft revolution counter reading (total revolutions) at the time of the speed change is recorded in column 4. The shaft revolution counter reading—as taken hourly on the hour, while underway—also is entered in column 4.

Ships and craft equipped with controllable reversible pitch propellers record in column 4 the propeller pitch in feet and fractions of feet set in response to a signaled speed change, rather than the shaft revolution counter readings. The entries for astern pitch are preceded by the letter B. Each hour on the hour, entries are made of counter readings, thus facilitating the calculation of engine miles steamed during those hours when the propeller pitch remains constant at the last value set in response to a signaled order.

Before going off watch, the engineering officer of the watch signs the Bell Book in the line following the last entry for his watch and the next officer of the watch continues the record immediately thereafter. In machinery spaces where an engineering officer of the watch is not stationed, the bell sheet is signed by the watch supervisor. (NOTE: A common practice is also to have the Throttleman sign the Bell Book prior to the EOOW or his relief.)

The Bell Book is maintained by bridge personnel in ships and craft equipped with controllable reversible pitch propellers, and in which the engines are directly controlled from the bridge. When control is shifted to the engineroom, however, the Bell Book is maintained by the engineroom personnel. The last entry made in the Bell Book on the bridge indicates the time that control is shifted and the first entry made in the Bell Book in the engineroom indicates the time that control is taken by the engineroom. Similarly, the last entry made by engineroom personnel indicates when control is shifted to the bridge. When the Bell Book is maintained by bridge personnel, it is signed by the OOD in the same manner as prescribed for the engineering officer of the watch.

Alterations or erasures are not permitted in the Bell Book. An incorrect entry is corrected by drawing a single line through the entry and recording the correct entry on the following line. Deleted entries are initialed by the engineering Officer of the watch, the OOD, or the watch supervisor, as appropriate.

OPERATING RECORDS AND REPORTS

Engineering operating records are meant to ensure regular inspection of operating machinery and to provide data for performance analysis. Operating records are not intended to replace frequent inspections of operating machinery by supervisory personnel and are not to be trusted implicitly to provide warning of impending casualties. Personnel who maintain operating records must be properly indoctrinated. They must be trained to correctly obtain, interpret, and record data, and to report any abnormal conditions encountered.

The type of commander's directives specify which engineering operating records will be maintained and prescribe the forms to be used when no standard record forms are provided. The engineer officer may require additional operating records when (all factors considered—including the burden of added paperwork) he deems them necessary.

The operating records discussed in this chapter are generally retained on board for a period of 2 years after which time they may be destroyed in accordance with current disposal regulations. Completed records must be stowed where they will be properly preserved, and in such a manner as to ensure that any one of the records can be easily located.

PROPULSION STEAM TURBINE AND REDUCTION GEAR OPERATING RECORD (NON-NUCLEAR SHIPS ONLY)

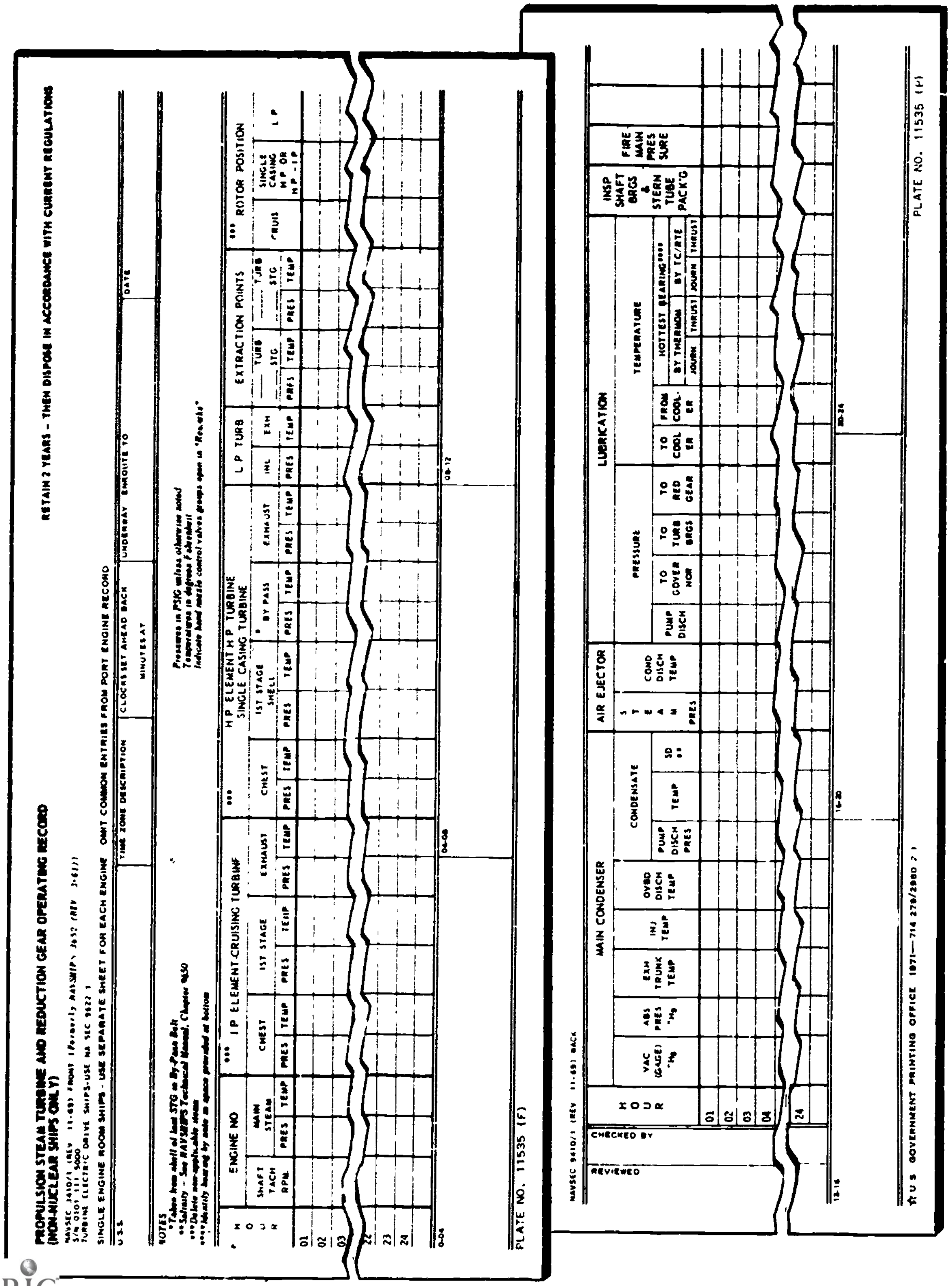
The Propulsion Steam Turbine and Reduction Gear Operating Record, NAVSEC 9410/1 fig. 16-2), is a daily record maintained for each main engine in operation. In ships with more than one main engine in the same engineroom, a separate sheet is maintained for each engine but common entries are omitted from the record for the port engine.

The watch supervisor enters the remarks and signs the record for his watch. The petty officer in charge of the engineroom checks the accuracy of the record and signs his name in the space provided on the back of the record. The main propulsion assistant notes the contents and signs the record. Any unusual conditions noted in the record are immediately reported to the engineer officer.

WARMING-UP AND SECURING SCHEDULES

The warming-up and securing schedules vary from ship to ship, depending on the procedure developed by the type commander. Each Machinist's Mate should become familiar with the type of check-off sheets used on his ship.

The purpose of the check-off sheet is to provide a guide to assist the MM1 and MMC in warming up or securing the main plant. Although experienced Machinist's Mates are capable of warming up and securing main plants, there are times when even the most experienced person will overlook a step in the procedure.



114.10

Figure 16-2.—Propulsion Steam Turbine and Reduction Gear Operating Record (Non-Nuclear Ships Only).

Hence these forms simplify matters and provide a convenient method of checking off the various steps in the procedure so that no steps will be overlooked. The check-off list is filled out by the petty officer in charge of warming up or securing the plant.

MONTHLY SUMMARY

The Monthly Summary of Fuel Inventory and Steaming Hours Report, shown in figure 16-3, is a comprehensive monthly of engineering data concerning the operating efficiency and general performance of the ship's engineering plant. The requirements for the report are contained in Fleet Commander Instructions. The original copy of the report, prepared by the engineer officer, and approved by the commanding officer, is sent to the fleet commander. One carbon copy of the report may be provided to the type commander, one carbon copy may be sent to the squadron commander (division commander for cruisers and carriers), and the last carbon copy is retained aboard ship, in the files of the engineering department. (NOTE: The requirement to send one copy to the squadron commander should be optional, based on the desires of the squadron commander.

The Monthly Summary provides current and cumulative data necessary for determining budget and fleet logistic requirements, and operational performance. The report includes all fuel data as of 2400 hours of the last day of the month, and is forwarded within 5 days of completion of the reporting month. Fleet Commander Instructions contain detailed instructions for completing the forms and definitions of the terms used.

In addition to data on fuel inventory the report contains space for fuel consumed underway, fuel consumed not underway, and fuel consumed by boats. Space is also provided for total steaming hours broken down as to underway, not underway.

Most engineer officers prefer to compile the necessary data for this summary on a daily basis rather than wait until the end of the month and make computations from the various records. In using either method, care must be taken to correctly compute and record the data on the Monthly Summary in order to avoid having to submit a corrected form at a later date. As a petty officer in the engineering department, you may be required to compile data for the monthly summary.

OPERATING INSTRUCTIONS AND SAFETY PRECAUTIONS

A master list of all the engineering department operating instructions and safety precautions is kept in the engineering log room. When a ship is commissioned, the building yard normally provides a master copy, in addition to posting the individual operating instructions and safety precautions throughout the engineering spaces. If any of the posted operating instructions and safety precautions are damaged or lost, a duplicate copy can be readily made up from the master list.

Where the operating instructions and safety precautions are not provided, they can be made up by the ship's force. The required instructions can be obtained from the manufacturer's technical manuals and from the appropriate chapters in *NavShips Technical Manual*.

DISPOSAL OF ENGINEERING RECORDS AND REPORTS

Before any engineering department records are destroyed, the *Disposal of Navy and Marine Corps Records, USN and USNS Vessels*, SECNAV P5212.5 (revised) should be studied. This publication informs ships of the Navy of the procedures used for disposing of records. For each department aboard ship, these instructions list permanent records which must be kept, and temporary records which may be disposed of in accordance with an established schedule.

Both the Engineering Log and Engineer's Bell Book must be preserved as permanent records on board ship for a 3-year period unless they are requested by a Naval Court or Board, or by the Navy Department, in which case, a copy (preferably photostatic) of such sheets or parts of these records that are sent away from the ship, is certified by the engineer officer as a true copy for the ship's files.

MONTHLY SUMMARY OF FUEL INVENTORY AND STEAMING HOURS REPORT
LANTFLT 3100/1 (New 7/70) 0103-631-0010

CINCLANTFLT REPORT 3100-4
(No letter of transmittal required. Submit by 5th of following month.)

FROM (Name, type, hull no.) USS	UIC	MONTH/YEAR
TO COMMANDER IN CHIEF U.S. ATLANTIC FLEET (CODE 042) NORFOLK, VA. 23511 — MAIN PROPULSION FUEL TYPE (Check one) ☐ NSFO ☐ DIESEL ☐ JP 5 ☐ DISTILLATE	OPR COR CODE (SEE REVERSE)	DAYS UNDERWAY

	NSFO (GALLONS)	DIESEL (GALLONS)	JP-5 (GALLONS)	DISTILLATE (GALLONS)
FUEL INVENTORY ON BOARD BEGINNING OF MONTH				
RECEIPTS DURING MONTH (+)				
GAIN BY INVENTORY (+)				
LOSS BY INVENTORY (–)				
TOTAL MONTHLY DELIVERIES (–)				
FUEL CONSUMED UNDERWAY (–)				
FUEL CONSUMED NOT UNDERWAY (–)				
FUEL CONSUMED FOR BOATS, AUX, ETC. (–)				
FUEL INVENTORY ON BOARD END OF MONTH (Bal)				

	UNDERWAY	NOT UNDERWAY	NOT STEAMING	TOTAL
TOTAL STEAMING HOURS				

FUEL RECEIPTS				FUEL DELIVERIES			
Date	From	Type	Gallons	Date	To	Type	Gallons

SUBMITTED	RECEIPTS VERIFIED	FORWARDED APPROVED
CHIEF ENGINEER	SUPPLY OFFICER	COMMANDING OFFICER

147.160

Figure 16-3.–Monthly Summary of Fuel Inventory and Steaming Hours Report.

At regular intervals, such as each quarter, the parts of those records that are over 3 years old are destroyed. When a ship that is less than 3 years old is decommissioned, the current books should be retained. If a ship is scrapped, the current books are forwarded to the nearest Naval Records Management Center.

Any reports forwarded to, and received from NAVSEA or other superior command may be destroyed when 2 years old, if they are no longer required for any other purpose.

It is important that only those reports which are required, or serve a specified purpose, be maintained on board ship. However, any report or record which will assist personnel in scheduling or making repairs, and which will supply personnel with information which is not contained elsewhere in publications or manuals, should be kept on board ship.

INDEX

☆U S GOVERNMENT PRINTING OFFICE: 1975-640-702/44