NONRESIDENT
TRAINING
COURSE

April 1987

Engineman 1 & C

NAVEDTRA 14075

NOTICE

Page 6-2 must be printed on a
COLOR printer

Although the words “he,” “him,” and “his” are used sparingly in this course to enhance communication, they are not intended to be gender driven or to affront or discriminate against anyone.

COMMANDING OFFICER
NETPDTC
6490 SAUFLEY FIELD RD
PENSACOLA, FL 32509-5237

ERRATA #1 12 Mar 1991

Specific Instructions and Errata for
Training Manual and
Nonresident Training Course

ENGINEMAN 1 & C

1. No attempt has been made to issue corrections for errors in typing, punctuation, etc., that do not affect your ability to answer the question or questions.

2. To receive credit for deleted questions, show this errata to your local course administrator (ESO/scorer). The local course administrator is directed to correct the course and the answer key by indicating the question deleted.

3. Assignment Booklet

Delete the following questions, and leave the corresponding spaces blank on the answer sheets:

Questions	Questions
3-69	8-46
7-32	9-21
7-40	9-22
7-53	

Make the following changes:

Question	Change
2-23	In the question, line 2, change the words "ship-to-ship" "to ship-to-shop."
3-35	In the question, line 4, delete the word "chief."
4-35	In choice 1, change the word "pressure" to read "presence" and delete the word "the" before "oil."
5-42	In choice 2, change the word "tapped" to read "tappet."

8-4	In the question, line 1, change the words "an air" to read "A."
In the instructions for answering questions 9-55 through 9-58	Change figure numbers "9-4" and "9-5" to read "7-4" and "7-5."

4. Textbook, Engineman 1 & C

Make the following changes:

Page	Column	Par.	Change
2-4	Right	2	Change "feed" to "feet."
8-14	Right	1	Change "chapter 63" to "chapter 631."
9-13	Left	3	Delete repeat sentence starting from "a few lights ending to switchboards."

PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

COURSE OVERVIEW: In completing this nonresident training course, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following: maintenance of engines, reduction gears, air-conditioning equipment, and additional auxiliary machinery; the performance and efficiency of an engine; engineering casualty control; engineering records and reports; and ship inspections and trials.

THE COURSE: This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

THE QUESTIONS: The questions that appear in this course are designed to help you understand the material in the text.

VALUE: In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

1983 Edition Prepared by
ENC Kenneth L. Butts

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AND TECHNOLOGY CENTER

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Sailor's Creed

"I am a United States Sailor.

I will support and defend the Constitution of the United States of America and I will obey the orders of those appointed over me.

I represent the fighting spirit of the Navy and those who have gone before me to defend freedom and democracy around the world.

I proudly serve my country's Navy combat team with honor, courage and commitment.

I am committed to excellence and the fair treatment of all."

CONTENTS

CREDITS

The illustrations indicated below are included in this edition of *Engineman 1 & C* through the courtesy of the designated sources. Permission to use these illustrations is gratefully acknowledged. Permission to reproduce illustrations and other materials in this publication should be obtained from the source.

Sources:	Figures:
Bacharach Industrial Instrument Company	3-1, 3-2, 3-3

INSTRUCTIONS FOR TAKING THE COURSE

ASSIGNMENTS

The text pages that you are to study are listed at the beginning of each assignment. Study these pages carefully before attempting to answer the questions. Pay close attention to tables and illustrations and read the learning objectives. The learning objectives state what you should be able to do after studying the material. Answering the questions correctly helps you accomplish the objectives.

SELECTING YOUR ANSWERS

Read each question carefully, then select the BEST answer. You may refer freely to the text. The answers must be the result of your own work and decisions. You are prohibited from referring to or copying the answers of others and from giving answers to anyone else taking the course.

SUBMITTING YOUR ASSIGNMENTS

To have your assignments graded, you must be enrolled in the course with the Nonresident Training Course Administration Branch at the Naval Education and Training Professional Development and Technology Center (NETPDTC). Following enrollment, there are two ways of having your assignments graded: (1) use the Internet to submit your assignments as you complete them, or (2) send all the assignments at one time by mail to NETPDTC.

Grading on the Internet: Advantages to Internet grading are:

- you may submit your answers as soon as you complete an assignment, and
- you get your results faster; usually by the next working day (approximately 24 hours).

In addition to receiving grade results for each assignment, you will receive course completion confirmation once you have completed all the assignments. To submit your assignment answers via the Internet, go to:

http://courses.cnet.navy.mil

Grading by Mail: When you submit answer sheets by mail, send all of your assignments at one time. Do NOT submit individual answer sheets for grading. Mail all of your assignments in an envelope, which you either provide yourself or obtain from your nearest Educational Services Officer (ESO). Submit answer sheets to:

COMMANDING OFFICER
NETPDTC N331
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32559-5000

Answer Sheets: All courses include one "scannable" answer sheet for each assignment. These answer sheets are preprinted with your SSN, name, assignment number, and course number. Explanations for completing the answer sheets are on the answer sheet.

Do not use answer sheet reproductions: Use only the original answer sheets that we provide—reproductions will not work with our scanning equipment and cannot be processed.

Follow the instructions for marking your answers on the answer sheet. Be sure that blocks 1, 2, and 3 are filled in correctly. This information is necessary for your course to be properly processed and for you to receive credit for your work.

COMPLETION TIME

Courses must be completed within 12 months from the date of enrollment. This includes time required to resubmit failed assignments.

PASS/FAIL ASSIGNMENT PROCEDURES

If your overall course score is 3.2 or higher, you will pass the course and will not be required to resubmit assignments. Once your assignments have been graded you will receive course completion confirmation.

If you receive less than a 3.2 on any assignment and your overall course score is below 3.2, you will be given the opportunity to resubmit failed assignments. **You may resubmit failed assignments only once.** Internet students will receive notification when they have failed an assignment--they may then resubmit failed assignments on the web site. Internet students may view and print results for failed assignments from the web site. Students who submit by mail will receive a failing result letter and a new answer sheet for resubmission of each failed assignment.

COMPLETION CONFIRMATION

After successfully completing this course, you will receive a letter of completion.

ERRATA

Errata are used to correct minor errors or delete obsolete information in a course. Errata may also be used to provide instructions to the student. If a course has an errata, it will be included as the first page(s) after the front cover. Errata for all courses can be accessed and viewed/downloaded at:

http://www.advancement.cnet.navy.mil

STUDENT FEEDBACK QUESTIONS

We value your suggestions, questions, and criticisms on our courses. If you would like to communicate with us regarding this course, we encourage you, if possible, to use e-mail. If you write or fax, please use a copy of the Student Comment form that follows this page.

For subject matter questions:

E-mail: n314.products@cnet.navy.mil
Phone: Comm: (850) 452-1001, Ext. 1826
DSN: 922-1001, Ext. 1826
FAX: (850) 452-1370
(Do not fax answer sheets.)
Address: COMMANDING OFFICER
NETPDTC N314
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32509-5237

For enrollment, shipping, grading, or completion letter questions

E-mail: fleetservices@cnet.navy.mil
Phone: Toll Free: 877-264-8583
Comm: (850) 452-1511/1181/1859
DSN: 922-1511/1181/1859
FAX: (850) 452-1370
(Do not fax answer sheets.)
Address: COMMANDING OFFICER
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NAVAL RESERVE RETIREMENT CREDIT

If you are a member of the Naval Reserve, you may earn retirement points for successfully completing this course, if authorized under current directives governing retirement of Naval Reserve personnel. For Naval Reserve retire- ment, this course is evaluated at 22 points. Points will be credited in units as follows:

Unit 1: 12 points upon satisfactory completion of assignments 1 through 5.

Unit 2: 10 points upon satisfactory completion of assignments 6 through 11.

(Refer to *Administrative Procedures for Naval Reservists on Inactive Duty,* BUPERSINST 1001.39, for more information about retirement points.)

Student Comments

Course Title: *Engineman 1 & C*

NAVEDTRA: 14075 **Date**: ____________________

We need some information about you:

Rate/Rank and Name: ____________________ SSN: ____________ Command/Unit ____________________

Street Address: ____________________ City: ____________ State/FPO: ________ Zip ________

Your comments, suggestions, etc.:

Privacy Act Statement: Under authority of Title 5, USC 301, information regarding your military status is requested in processing your comments and in preparing a reply. This information will not be divulged without written authorization to anyone other than those within DOD for official use in determining performance.

NETPDTC 1550/41 (Rev 4-00

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 many 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 everyday practical experience, should help you learn to perform assigned tasks and accept greater responsibilities.

RESPONSIBILITIES AND REWARDS

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 that 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 an EN3, the Navy rewarded you with an increase in pay and responsibility, a responsibility not only for yourself but 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 Engineman 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 specific to your rating and are directly related to the nature of your work. Operating and maintaining the machinery and equipment for which an Engineman is responsible is a job of vital importance. It is a teamwork job which requires that 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 administration, supervision, and training are discussed in subsequent chapters of this training manual. At this point, let's consider some of the broader aspects of your ever increasing responsibilities for military and technical leadership.

YOUR RESPONSIBILITIES WILL EXTEND BOTH UPWARD AND DOWNWARD. Officers and Supervisors will expect you to carry out their orders. 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 pertaining to the enlisted personnel.

YOU WILL HAVE REGULAR AND CONTINUING RESPONSIBILITIES FOR TRAINING. Even if you are fortunate enough to have a highly skilled and well trained group, you will still find that additional training is necessary. For example, you will always be responsible for training lower rated personnel to perform their assigned tasks. Occasionally, some of your best workers may be transferred and replaced by inexperienced or poorly trained personnel. Also, some particular job may call for skills that none of your personnel have. These and similar problems will require you to be a training specialist who can train individuals and groups in the effective execution of assigned tasks.

YOU WILL HAVE INCREASING RESPONSIBILITIES FOR WORKING WITH OTHERS. You will find that many of your plans and decisions affect a large number of people, some of whom are not in your division 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/her 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 function 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. You must be able to convey information accurately, simply, and clearly.

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 for effective communication is precision in the use of technical terms. Command of the technical language of the Engineman rating will enable you to exchange ideas with other personnel of the same rating. Personnel who do not understand the precise meaning of terms used in connection with the work of their own rating are at a disadvantage when they try to read official publications relating to their work. They are also at a great disadvantage when taking written examinations for advancement. Although it is always important to use technical terms correctly, it is particularly important when you are dealing with lower rated personnel. Sloppiness in the use of technical terms may be extremely confusing and frustrating to an inexperienced person.

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 an EN1, and even more as an ENC, 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; others you will have to look for. Try to develop a special kind of alertness for new information. Keep up to date on all sources of technical information. Information on sources of primary concern to the Engineman is given later in this chapter.

As you prepare to assume increased responsibilities at a higher level, you need to be familiar with (1) the military requirements and occupational standards given in the *Navy Enlisted Manpower and Personnel Classifications and Occupational Standards,* NAVPERS 18068 (with changes); (2) the Personnel Advancement Requirement (PAR), NAVPERS 1414/4; (3) appropriate rate training manuals; and (4) any other material that may be required or recommended in the most current edition of the *Bibliography for Advancement Examination Study,* NAVEDTRA 10052. These materials and their use are discussed more thoroughly in *Military Requirements for Petty Officers 1 & C,* NAVEDTRA 10057 (current edition), and *Engineman 3 & 2,* NAVEDTRA 10541 (current edition). Other sources of information will be described later in this chapter.

THE ENGINEMAN—YOUR JOB

Since you first became a rated person you have mastered basic skills, became familiar with much of the terminology applicable to internal combustion engines and other equipment, and learned to answer many of the technical questions asked by lower rated personnel. Along with this increase in knowledge, you have gradually assumed greater responsibilities. The rate for which you are now preparing demands more knowledge and skill, a willingness to assume greater responsibility, and the ability to lead people.

As an EN1 or ENC, you must be familiar with all the functions of the engineering department and be proficient in a wide variety of tasks. Your duties will include using proper procedures for troubleshooting, maintenance and repair, planning, organizing, and carrying out the work involved in these procedures. You will maintain records and submit reports; you will supervise the stowage of supplies and repair parts; and you will take an active part in the training of lower rated personnel. In brief, you will be a technical specialist and a military leader.

MILITARY DUTIES AND RESPONSIBILITIES

Information related to the military requirements for advancement is included in training manuals specifically prepared to cover such requirements. These manuals are listed and described briefly later in this chapter.

TECHNICAL DUTIES AND RESPONSIBILITIES

A petty officer must become a technical specialist in his/her rating. Technical duties which an Engineman must learn to perform efficiently include:

1. Operating internal combustion engines and auxiliary engineroom machinery.
2. Maintaining internal combustion engines and related accessories and equipment.
3. Performing overhaul and repair work on internal combustion engines, using established procedures for disassembly, replacement, and reassembly.
4. Conducting routine tests and inspections of all engineroom machinery.
5. Operating and making repairs to auxiliary boilers and to refrigeration, air conditioning, and distilling systems.
6. Using lathes and other machine shop equipment.
7. Using measuring instruments needed in engine overhaul, such as micrometers, feeler gages, and inside and outside calipers.
8. Reading accurately such instruments as thermometers, pressure gages, and pressure indicators.

Probably you can already do many of these jobs. Others you will have to learn from additional practical experience and through study. Although you will be learning many new jobs as an EN1, and especially as a ENC, you will be concerned principally with directing and observing the work of personnel assigned to you. You will be responsible for their performance and their training in all of the jobs required of an Engineman.

In addition to the duties already mentioned, you will compile necessary data for the preparation of engineering reports and records. It will be your duty to make frequent tours of assigned spaces, and to inspect equipment for proper operation. You will check the auxiliary watch for performance of duty in accordance with standing orders. You will be responsible for the use of the correct operating procedure for all equipment under your jurisdiction. You will be accountable for daily routine inspections, tests, and reports on all equipment that require daily maintenance and testing.

You may be held responsible to the division officer for the proper setting and standing of all watches during your duty period. You may be required to post the daily watch list in the engineroom and may be responsible for instructing and training watchstanders in their duties.

You will instruct lower rated personnel in the correct procedures to be used for casualties involving the engineroom. It will be your responsibility to see that personnel under your supervision learn about the capabilities and limitations of the equipment with which they work, and the procedures to follow should casualties occur.

Safety is a responsibility of all Navy personnel. As an EN1 or ENC, you will instruct your personnel in shipboard safety precautions, particularly those that are applicable to your division, and will ensure that copies of these precautions are posted in conspicuous places. Most importantly, you will watch for careless methods of work—the frequent source of accidents. You will be expected to set a good example for following safety practices. The example you will set will have a great influence on your people and other personnel. You will watch for and report all unsafe conditions.

To successfully perform your duties, you should know the duties performed in other divisions, and how the various shops can help you get a job done. While it is true that many maintenance and repair jobs occurring in your own division can be properly handled from start to finish without the aid of any outside rating, other jobs may be more extensive and may require special skills or equipment not available within your division. Although you and the personnel under your supervision may be able to do the bulk of the work, certain portions of a job may require the skill of an Electrician's Mate, a Machinist's Mate, a Machinery Repairman, a Hull Maintenance Technician, or people in other ratings. Therefore, you must know what equipment is used by other ratings in the engineering department, and what kind of work can be done with that equipment. Familiarize yourself with the work performed and equipment used in other divisions by observing them at work and by talking to leading petty officers in other ratings. There is no excuse for using unskilled personnel and unsatisfactory procedures when the skill of other ratings and the equipment they use are already available.

WATCH DUTIES AND RESPONSIBILITIES

As a first class or chief petty officer aboard ship, you may be required to assist the division officer in organizing, supervising, and instructing other personnel in their military duties as well as in their specialties. This duty includes assisting in the assignment of watch stations and other duties.

Every watch in the engineering department is a vital part of the ship's maintenance and operation program. The engineer officer is responsible for the operation and maintenance of the main engines and auxiliary machinery. However, the EN1s or ENCs and the personnel they supervise on the various watches actually do most of the work. Therefore, it is very important that the petty officers in charge learn and understand the extent of their responsibility to the engineer officer.

Engineering Officer of the Watch

The following excerpts from chapter 10 of *Navy Regulations* describe some of the duties of the officer of the engineroom watch:

> "Status, Authority, and Responsibility. The engineering officer of the watch is the officer on watch in charge of the main propulsion plant of the ship, and of the associated auxiliaries. He shall be responsible for the safe and proper operation of such units, and for the performance of the duties prescribed in these regulations and by other competent authority."

> "Directing and Relieving the Engineering Officer of the Watch. The engineer officer, or in his absence, the main propulsion assistant may direct the engineering officer of the watch concerning the duties of the watch, or may assume charge of the watch, and shall do so should it, in his judgment, be necessary."

> "Relation with the Officer of the Deck. The engineering officer of the watch shall ensure that all orders received from the officer of the deck are promptly and properly executed. He shall not permit the main engines to be turned except as authorized or ordered by the officer of the deck."

"Reports by the Engineering Officer of the Watch. The engineering officer of the watch shall report promptly to the officer of the deck and the engineer officer any actual or probable derangement of machinery, boilers, or auxiliaries which may affect the proper operation of the ship."

"Reports to the Engineering Officer of the Watch. The engineering officer of the watch shall be promptly informed of any engineering work or change in disposition of machinery which may affect the proper operation of the plant or endanger personnel, or which is required for entry in the record of his watch."

"Inspection and Operation of Machinery. The engineering officer of the watch shall cause frequent inspections to be made of the engines, boilers, and their auxiliaries; and shall ensure that prescribed tests, methods of operation, and instructions pertaining to the safety of personnel and material are strictly observed."

"Records and Logs. The engineering officer of the watch shall ensure that the engineering log, engineer's bell book, and prescribed operating records are properly kept. On being relieved, he shall sign the engineering log and the engineer's bell book for that watch."

Engineering Department Duty Officer

In ships not underway, the commanding officer may authorize the standing of a day's duty in lieu of the continuous watch of the engineering officer of the watch. When authorized, the duties of the engineering officer, of the watch are assigned in port to the engineering department duty officer. However, when not at the station of the engineering officer of the watch, the duty officer must always be ready for duty the moment he/she is summoned or notified that his/her presence is required. The engineering department duty officer, assigned by the engineer officer, must be a qualified engineering officer of the watch. On some ships, chief petty officers may be assigned as the engineering department duty officer.

In the temporary absence of the engineer officer, the duties of the engineer officer may be performed by the engineering department duty officer. If the engineer officer is on board, the duty officer reports the condition of the department to him/her prior to the eight o'clock reports. In the absence of the engineer officer, the duty officer makes the eight o'clock reports for the department to the executive officer (or command duty officer).

The engineering duty officer, in addition to such other duties as may be properly assigned to him/her, is responsible for:

1. The alertness and proper performance of all personnel of the engineering watches.

2. The safe and economical operation of all engineering machinery and systems in use.

3. The elimination of fire and flooding hazards and the prevention of sabotage.

4. The security of all engineering spaces. In order to determine the actual conditions that exist in the engineering space and to evaluate the performance of watch personnel, the duty officer must make frequent inspections of the engineering spaces.

5. The proper maintenance of all machinery operating logs, and for writing and signing the engineering log for the period he/she is on duty.

The engineering department duty officer makes reports in the same manner as the engineering officer of the watch, except that when acting in place of the engineer officer, he/she is responsible for making the reports required of that officer. Engineering watch supervisors and the duty petty officers of the engineering divisions report to the duty officer during the performance of their duties.

A chief petty officer who is a qualified engineroom watch supervisor underway may be assigned a watch as the engineering department duty chief petty officer to assist the engineering department duty officer. The duty chief petty officer is normally assigned duty for the same period as the duty office, and reports to that officer.

Standing Watches

As a watchstander, you will be the “eyes” of the engineering department. You will be responsible for the orderly appearance and cleanliness of your assigned station. Prior to standing watch, you should thoroughly inspect all existing conditions, such as the operating condition of machinery and firefighting equipment. You should also check your assigned area for leaks and potential fire hazards. If a casualty occurs, you should take immediate steps to control it, as well as promptly notify the proper authority.

While on watch, you should strictly observe all operating instructions, regulations, and safety precautions. You should never leave your station unless you have permission from proper authority to do so, or are properly relieved. You should promptly execute all standing or special orders. When relieved, you should pass on to the relieving watch all information concerning existing conditions and special orders.

There are several watches that you may stand or for which you may be responsible. The stations and duties of some of the watches commonly stood by Enginemen are discussed in the following paragraphs.

ENGINEROOM AUXILIARY WATCH.—Auxiliary watches are maintained underway and in port to supply light, power, steam, and other services. The engineroom auxiliary watch maintained in port includes a petty officer in charge and one or more Firemen. The petty officer in charge is responsible for seeing that an efficient and economical watch is being stood. All machinery not in operation must be checked to see that it has been properly secured.

The petty officer in charge of the auxiliary watch is responsible for the proper operation of the ship’s service generator and associated machinery; however, the operation of the electrical equipment is the responsibility of an Electrician’s Mate. The petty officer in charge checks to see that all operating machinery is lubricated as prescribed by the operating instructions. He/she makes sure that the fire and flushing pumps are inspected for satisfactory operation and that the prescribed pressure is maintained in the firemain.

Except in emergencies, the engineroom auxiliary watch does not make any changes such as stopping, starting, or shifting ship’s service generators without first notifying the Electrician’s Mate and the petty officer in charge of the watch.

A watch going off duty will not be considered relieved until the floor plates are wiped, the engineroom is clean, all operating logs and records are correct, and information concerning the status of the machinery in operation, orders, special orders, and non-completed orders have been given to the relief.

COLD-IRON WATCHES.—Under certain prescribed conditions (such as when a ship moves alongside a repair ship or tender, or into a naval shipyard, and is receiving power from these activities) a security and fire watch is usually set by each division. This security watch is commonly known as a cold-iron watch. Each cold-iron watch makes frequent inspections of the assigned area and checks for fire hazards, flooding, or other unusual conditions throughout the area. The cold-iron watch keeps bilges reasonably free of water in accordance with applicable instructions. Hourly reports on existing conditions are made to the officer of the deck.

All unusual conditions are immediately reported to the officer of the deck and to the engineering duty officer, so that the proper division or department can be notified to take the necessary corrective measures. When welding or burning is to be performed in the area, the cold-iron watch checks to see that a fire watch is stationed.

If the ship is in drydock, the watch must check all sea valves, after working hours, to see that the valves are secured or blanked off. The watch must make sure that oil or water is not being pumped into the drydock and that weights such as fuel oil, feedwater, or potable water are not shifted without permission of the engineer officer.

DUTY ASSIGNMENTS

As an Engineman, you will be assigned duty aboard various types of ships, ranging from aircraft carriers to the smallest of river patrol boats. You will also be assigned shore duty. Your specific duties will depend on the type and size of ship or station to which you will be assigned.

Aboard an aircraft carrier or a cruiser, you may be assigned to the "A" division. As a member of the "A" gang, you will be responsible for a wide variety of tasks including the operation, maintenance and repair of internal combustion engines, and the operation and maintenance of auxiliary, refrigeration, and air conditioning equipment.

On diesel-driven ships, you may be assigned to the "M" division or the "A" division. Your responsibility will vary depending on the size of the ship. You may have charge of one of the engineering spaces or the "A" gang and, on some small ships, you may act as the "M" division officer.

On a repair ship or tender, you may be assigned to the repair department. As an EN1 or ENC, you may be in charge of one of the repair shops such as the engine overhaul shop or the governor and fuel injector shop, or you may be in charge of one of the repair gangs. You may also be selected to attend Diesel Inspector's school and become a Navy diesel engine inspector.

Duty at most shore stations will depend on your training and your field of specialization. You may also be assigned as an instructor either at one of the Engineman schools or at a recruit training station, or a canvasser recruiter. To qualify for instructor duty, you must successfully complete a course in instructor training.

As an Engineman, you may perform duty at the Naval Education and Training Program and Development Center, Pensacola, FL. Personnel assigned to this activity are involved in either the preparation of service-wide examinations for advancement or the preparation and revision of rate training manuals and other training materials.

SCOPE OF THIS TRAINING MANUAL

Before studying any book, it is a good idea to know the purpose and the scope of that 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 EN1 and ENC.

- It must be satisfactorily completed before you can advance to EN1 or ENC, 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 EN3 and EN2. Such information is given in *Engineman 3 & 2,* NAVEDTRA 10541 (current edition).

- The occupational qualifications that were used as a guide in the preparation of this training manual were those promulgated in the *Navy Enlisted Manpower and Personnel Classifications and Occupational Standards,* NAVPERS 18068-D (1981). Therefore, changes in the Engineman qualifications that may have occurred after the D edition became effective may not be reflected in the information given in this training manual.

- This training manual includes information that is related to both the knowledge and the Occupational Standards for advancement to EN1 and ENC. However, no training manual can take the place of actual on-the-job experience for developing skill in the practical factors. This 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 *Personnel Advancement Requirement,* NAVPERS 1414/4, should be utilized in conjunction with this training manual whenever possible.

- Subsequent chapters in this training manual deal with the technical subject matter of the Engineman rating. Before studying these chapters, study the table of contents and note the arrangement of information. 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 Engineman 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 EDUCATION AND TRAINING (NAVEDTRA) PUBLICATIONS

Originally, training manuals were developed by the Chief of Naval Training and carried the designation NAVTRA followed by a number. In 1973, the Naval Education and Training Production Development Center (NETPDC) came directly under the command of the Chief of Naval Education and Training (CNET). Training materials published by NETPDC after the above date are designated NAVEDTRA in lieu of NAVTRA; however, the numbers remain as originally assigned for most publications. The designators of publications printed prior to 1973 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 Examination 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 each year by the Naval Education Training and Program Development Center. Each revised edition is identified by a letter following the NAVEDTRA number. When using this publication, be SURE you have the most recent edition.

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

Rate training manuals that are marked with an asterisk (*) in NAVEDTRA 10052 are MANDATORY at the indicated levels. A mandatory training manual may be completed by (1) passing the appropriate Enlisted Correspondence 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 graduating from an appropriate Navy school.

It is important to note that all references, whether mandatory or recommended, listed in NAVEDTRA 10052, may be expected to be used as source material for the written examinations at the appropriate levels. In addition, references listed in a rate training manual may also be used as source material for examination questions.

Rate Training Manuals

Most 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 a particular rating.

Rate training manuals are revised from time to time to bring them up to date. The revision of a rate training manual is identified by a letter following the NAVEDTRA number. You can tell whether or not a rate training manual you are using is the latest edition by checking the NAVEDTRA number and the letter following it 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 I & 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; on how to prepare for advancement; on how to supervise, train, and lead other people; and on how to meet increasing responsibilities as you advance in rating.

Some of the rate training manuals that may be useful to you when you are preparing to meet the occupational qualifications for advancement are discussed briefly in the following paragraphs.

Tools and Their Uses, NAVEDTRA 10085 (current edition), 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 (current edition), chapters 1 through 4 and chapter 7, recommended reading in preparing for advancement to EN2. The remainder of the training manual contains additional information that may be of value to you as you prepare for advancement to EN1 and ENC.

Mathematics, Vol. 1, NAVEDTRA 10069 (current edition), and *Mathematics, Vol. 2,* NAVEDTRA 10071 (current edition), may be helpful if you need to brush up on your mathematics. Volume 1 contains basic information that is needed for using formulas and for making simple computations. Volume 2 contains more advanced information than you will need for most purposes. However, occasionally, you may find the information in this book to be helpful.

Engineman 3 & 2, NAVEDTRA 10541 (current edition), must be satisfactorily completed for advancement to EN3 and EN2. If you have met this requirement by satisfactorily completing earlier editions of training manuals prepared for Enginemen, you should at least become familiar with *Engineman 3 & 2,* NAVEDTRA 10541 (current edition). Much of the information given in this edition of *Engineman I & C* is based on the assumption that you are familiar with the contents of *Engineman 3 & 2,* NAVEDTRA 10541 (current edition).

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 broaden your knowledge of the duties and skills of other personnel in the engineering department. The training manuals prepared for Machinist's Mates, Boiler Technicians, and Machinery Repairmen are likely to be of particular interest to you.

For a complete listing of rate training manuals, consult the *List of Training Manuals and Correspondence Courses*, NAVEDTRA 10061 (latest revision).

Correspondence Courses

Most rate training manuals and officer texts are used as the basis for correspondence courses. Credit for the completion of a mandatory training manual is earned by passing the correspondence course that is based on that training manual. You will find it helpful to take other correspondence courses, as well as those that are based on mandatory training manuals. A correspondence course helps you to master the information given in the training manual or text. It also gives you a good idea of how much you have learned.

NAVSEA PUBLICATIONS

A number of publications issued by the Naval Sea Systems Command (NAVSEA) 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 NAVSEA publications.

The *Naval Ships' Technical Manual* is a basic doctrine publication of NAVSEA. To allow the ship to distribute copies to the working spaces where information is required, chapters are now issued as separate paper-bound volumes. Chapters are kept up to date by means of yearly revisions. Chapters are reviewed less frequently where yearly revisions are not necessary. In chapters where intra-year changes are required, either an intra-year edition or a NAVSEA Notice is distributed as a temporary supplement for use pending issue of the new edition of the chapter.

You will find chapters in *Naval Ships' Technical Manual* of particular importance to the Engineman referenced in this training manual. For a list of all chapters in the manual, see appendix A, chapter 001.

The *Deck Plate* is a monthly publication which contains interesting and useful information on all aspects of shipboard engineering. This magazine is particularly useful because it presents information which supplements and clarifies information contained in the *Naval Ships' Technical Manual* and because it presents information on new equipment, policies, and procedures.

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 of machinery and equipment. The manufacturers' technical manuals for internal combustion engines and associated equipment are usually given NAVSEA numbers.

TRAINING FILMS

Training films which are available to naval personnel are a valuable source of supplementary information on many technical subjects. Films that may be of interest to you are listed in the *Department of the Navy Catalog of Audiovisual Production Products,* OPNAVINST 3 157.1.

When selecting a film, note its date of issue 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. When you plan to show a film to train personnel, take a look at it in advance if possible so that you may spot material that may have become obsolete, then verify current procedures by looking them up in the appropriate sources before showing the film.

CHAPTER 2

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 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 forms and reports are submitted.

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 an Engineman, you will have administrative and supervisory responsibilities in connection with engineroom and auxiliary operations and with equipment maintenance and repair.

OPERATIONAL RESPONSIBILITIES

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 the 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.

In order for you to monitor and record your plant's status and performance, you need to know which engineering records and reports for the administration, maintenance, and repair of naval ships are prescribed by directives from such authorities as the Type Commander, Naval Ship Systems Command (NAVSHIPS), and Chief of Naval Operations (CNO). These records must be accurate and up to date in accordance with current instructions.

As an EN3 and EN2, you have been primarily concerned with operating logs and similar records. As an EN1 or ENC, 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 the most common engineering records and reports is given in this chapter. These standard forms are prepared by the various systems commands and CNO. The forms are for issue to forces afloat and can be obtained as indicated in the *Navy Stock List of Forms and Publications,* NAVSUP 2002. Since these forms are revised as conditions warrant, personnel ordering forms must be sure that the most 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, NAVSEA 3120/2 (figure 2-1), and the Log Continuation Sheet, NAVSEA 3120/2A, are used to record important daily events and data pertaining to the engineering department and the operation of the engineering plant. A table is provided in the log for recording the hourly average rpm (to the nearest tenth) of all shafts and the resultant speed, in knots. Additional tables and spaces are provided for recording the ship's draft and displacement (upon getting underway and anchoring or mooring); the total engine miles steamed for the day and the distance traveled through water; the number of days out of dock; the amount of fuel, water, and lubricating oil on hand, received, and expended; the name of the ship, the date, and the location or route of the ship; and remarks chronicling important events.

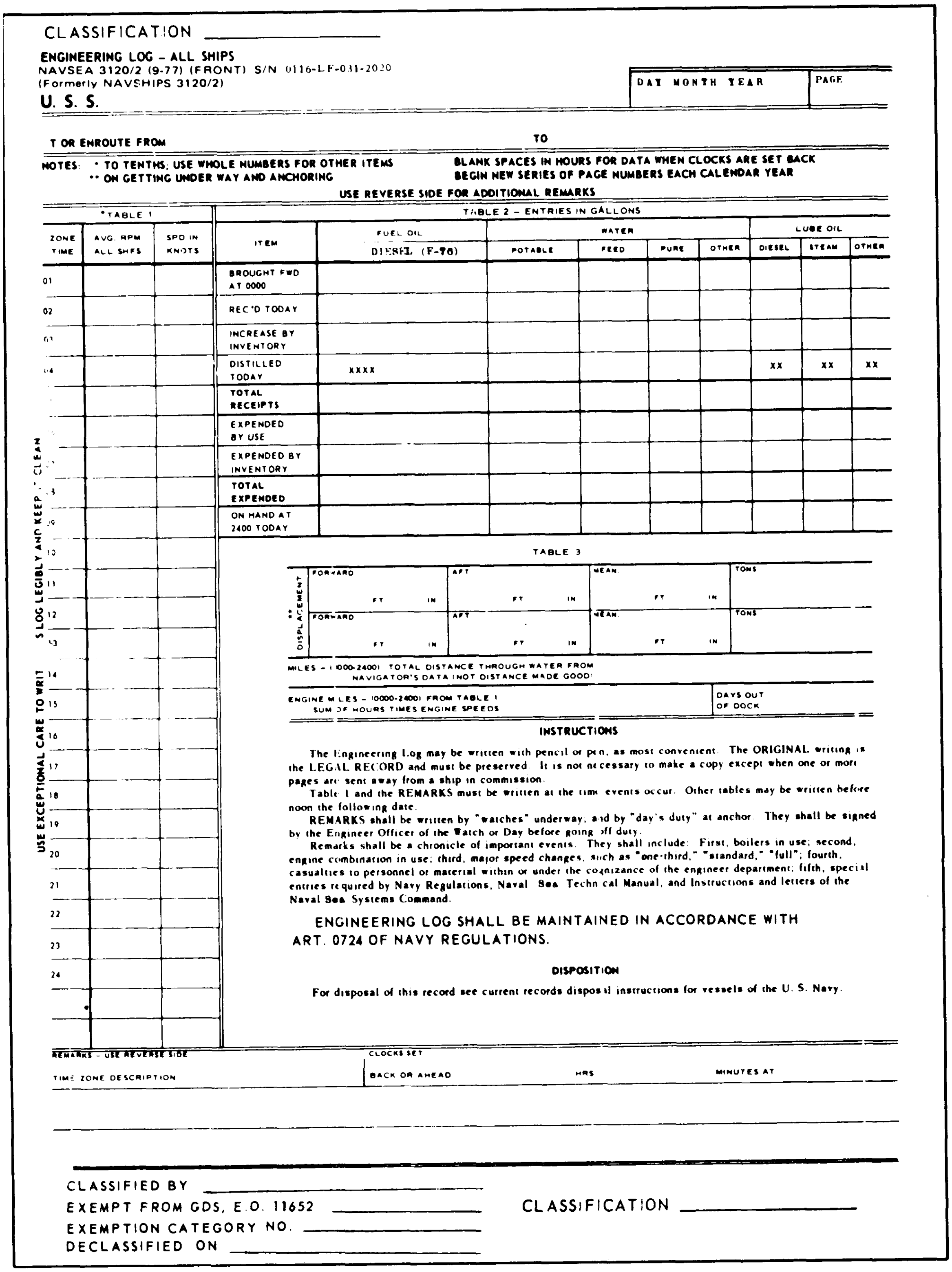
Entries in the Engineering Log must be made in accordance with instructions given (1) on the log sheet (NAVSEA 3120/2), (2) in chapter 10 of *U.S. Navy Regulations, (3)* in *Naval Ships' Technical Manual,* chapter 9004, and (4) in directives of the type commander.

Remarks written in the Engineering Log must include (1) boilers in use, (2) engine combination in use, (3) major speed changes (such as 1/3, 2/3, standard, and full), (4) all injuries to personnel occurring within the department, (5) casualties occurring to material under the cognizance of the engineering department, and (6) such other matters as may be specified by competent authority. 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 (EOOW) (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 the log 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).

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 this event the



CLASSIFICATION ____________

ENGINEERING LOG – ALL SHIPS
NAVSEA 3120/2 (9-77) (FRONT) S/N 0116-LF-031-2020
(Formerly NAVSHIPS 3120/2)

U. S. S.

DAY MONTH YEAR	PAGE

T 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

*TABLE 1

ZONE TIME	AVG. RPM ALL SHFS	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		

USE EXCEPTIONAL CARE TO WRITE LOG LEGIBLY AND KEEP IT CLEAN

TABLE 2 – ENTRIES IN GALLONS

ITEM	FUEL OIL	WATER				LUBE OIL		
	DIESEL (F-76)	POTABLE	FEED	PURE	OTHER	DIESEL	STEAM	OTHER
BROUGHT FWD AT 0000								
REC'D TODAY								
INCREASE BY INVENTORY								
DISTILLED TODAY	XXXX					XX	XX	XX
TOTAL RECEIPTS								
EXPENDED BY USE								
EXPENDED BY INVENTORY								
TOTAL EXPENDED								
ON HAND AT 2400 TODAY								

TABLE 3

** DISPLACEMENT	FORWARD	AFT	MEAN	TONS
	FT IN	FT IN	FT IN	
	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 Sea Technical Manual, and Instructions and letters of the Naval Sea Systems Command.

ENGINEERING LOG SHALL BE MAINTAINED IN ACCORDANCE WITH ART. 0724 OF 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

CLASSIFIED BY ____________
EXEMPT FROM GDS, E.O. 11652 ____________
EXEMPTION CATEGORY NO. ____________
DECLASSIFIED ON ____________

CLASSIFICATION ____________

98.162

Figure 2-1.—Engineering Log—All ships.

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.

Completed Engineering Log sheets are filed in a post-type binder. Pages of the log are numbered consecutively with a new series of page numbers commencing with the first day of each calendar year.

ENGINEER'S BELL BOOK.—The Engineer's Bell Book, NAVSEA 3120/ 1 (figure 2-2), 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 may be 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 (figure 2-2).

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. (NOTE: When the order received is recorded as rpm in column 2 (minor speed changes), no entry is made in column 3.)

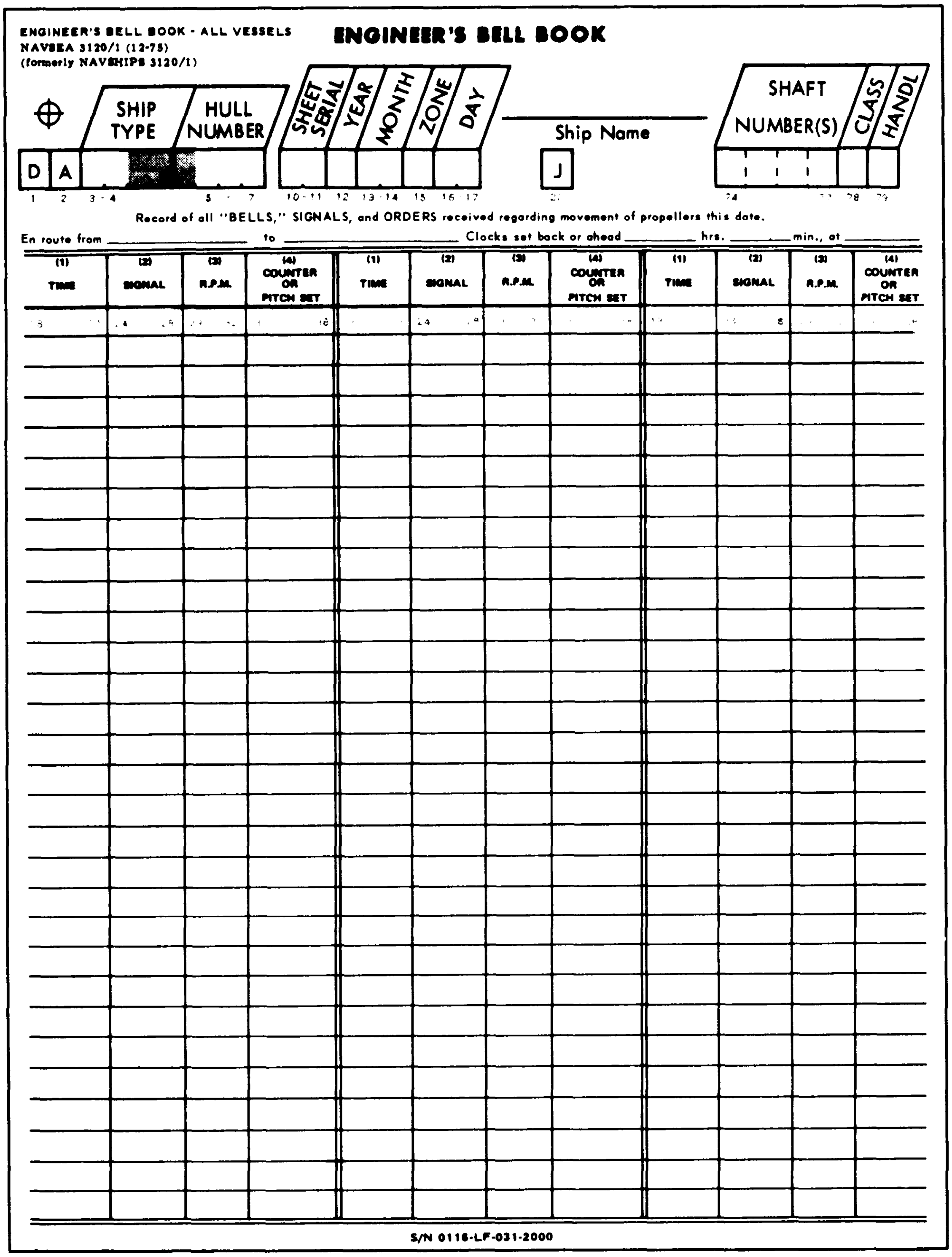
5. The shaft revolution counter reading (total rpm) at the time of the speed change is recorded in column 4. The shaft revolution counter reading—as taken hourly on the hour, while underway—also is entered in column 4.

Ships and craft equipped with controllable reversible pitch propellers record in column 4 the propeller pitch in feed 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 EOOW signs the Bell Book on the line following the last entry for his watch and the next EOOW continues the record immediately thereafter. In machinery spaces where an EOOW is not stationed, the bell sheet is signed by the watch supervisor.

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 the bridge personnel, it is signed by the officer of the deck (OOD) in the same manner as prescribed for the EOOW.

Alterations or erasures are not permitted in the Bell Book. An incorrect entry is corrected by



ENGINEER'S BELL BOOK - ALL VESSELS
NAVSEA 3120/1 (12-75)
(formerly NAVSHIPS 3120/1)

ENGINEER'S BELL BOOK

SHIP TYPE	HULL NUMBER	SHEET SERIAL	YEAR	MONTH	ZONE	DAY	Ship Name	SHAFT NUMBER(S)	CLASS	HANDL
D A							J			

Record of all "BELLS," SIGNALS, and ORDERS received regarding movement of propellers this date.

En route from ______ to ______ Clocks set back or ahead ______ hrs. ______ min., at ______

(1) TIME	(2) SIGNAL	(3) R.P.M.	(4) COUNTER OR PITCH SET	(1) TIME	(2) SIGNAL	(3) R.P.M.	(4) COUNTER OR PITCH SET	(1) TIME	(2) SIGNAL	(3) R.P.M.	(4) COUNTER OR PITCH SET

S/N 0116-LF-031-2000

Figure 2-2.—Engineer's Bell Book, NAVSEA 3120/1.

drawing a single line through the entry and recording the correct entry on the following line. Deleted entries are initialed by the EOOW, 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 noted.

The type 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.

DIESEL ENGINE OPERATING RECORD.—The Diesel Engine Operating Record-all Ships, NAVSEA 9231/2 (figures 2-3 and 2-4), is a daily record maintained for each operating diesel engine. In ships with more than one main engine in the same engineroom, a separate record sheet is maintained for each operating engine.

The watch supervisor enters the remarks and signs the record for his watch. The petty officer in charge of the engineroom or the senior engineman checks the accuracy of the record and signs the record in the space provided on the back of the record. Any unusual conditions noted in the record are immediately reported to the engineer officer and the record is sent to the engineer officer for approval.

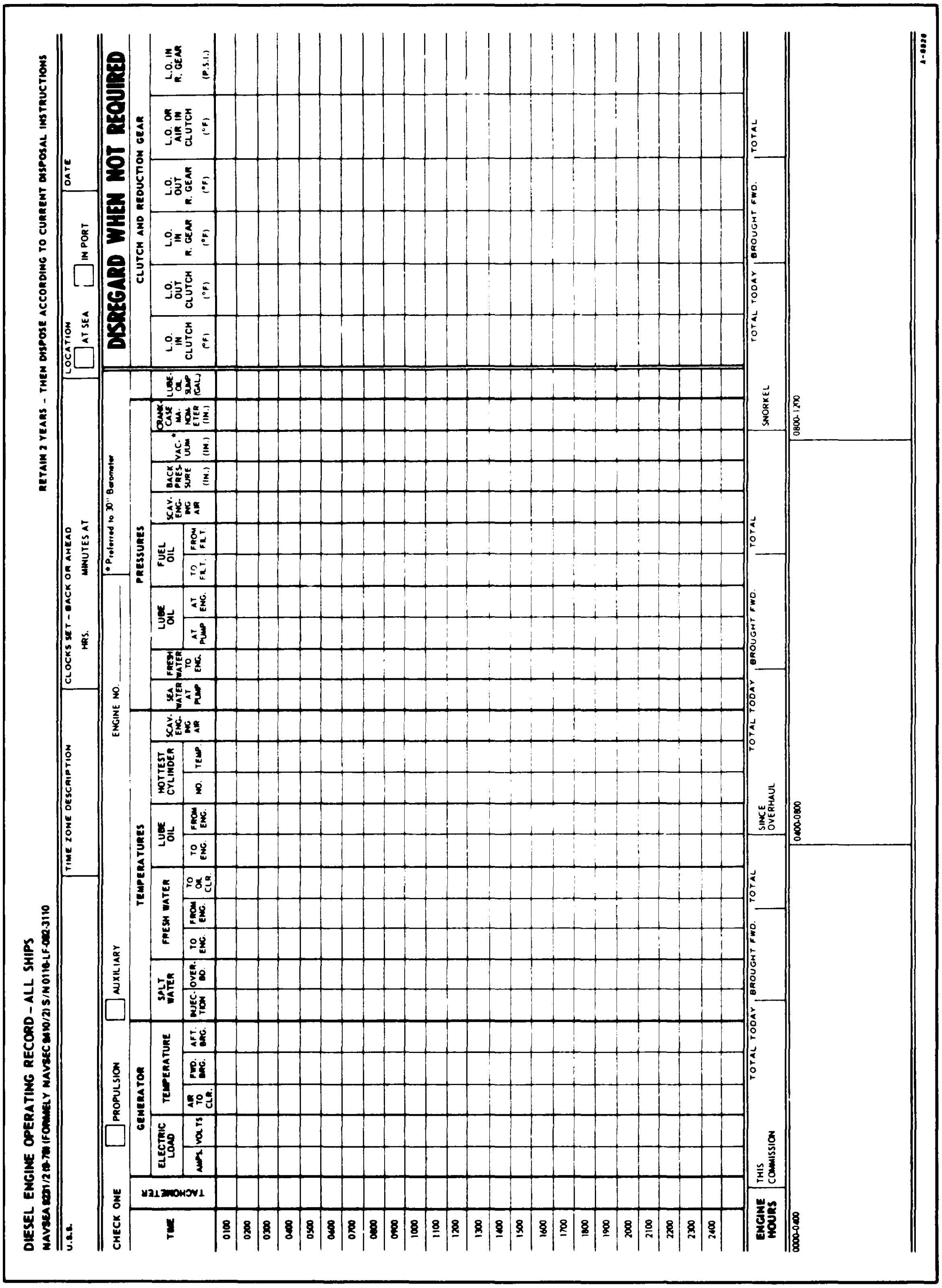
FUEL AND WATER ACCOUNTS.—The maintenance of daily diesel fuel, lubricating oil, and water accounts is vital to the efficient operation of the engineering department. Forms and procedures necessary to account for and preserve a limited supply of freshwater and fuel are generally prescribed by the type commanders.

Principally, the accounts inform the engineer officer of the status of the ship's liquid load and form the basis of reports submitted to higher authority by the engineer officer.

It is fundamental to all naval operations that the ship and unit commanders know the exact amount of burnable fuel on hand. When computing the amount of burnable fuel on board, consider only the fuel in the service and storage tanks. All the fuel below the fuel suction line is to be considered not burnable.

FUEL AND WATER REPORTS.—The Fuel and Water Report, NAVSEA 9255/9 (figures 2-5 and 2-6), is a report submitted daily to the commanding officer. This report indicates the amount of fuel oil and water on hand as of midnight, the previous day. The Fuel and Water Report also includes the previous day's feed and potable water performance and results of water tests. The original and one copy are submitted to the OOD in sufficient time for submission to the commanding officer or command duty officer with the 1200 reports. The copy is retained by the OOD.

MONTHLY SUMMARY.—The Monthly Summary of Fuel Inventory and Steaming Hours Report is a comprehensive monthly report of engineering data from which the operating efficiency and general performance of the ship's engineering plant can be calculated (see figure 2-7). Requirements for this report are contained in Fleet Commander Instructions. This report is prepared by the engineer officer and verified, as to fuel receipts, by the supply officer. Then, it is approved and forwarded by the commanding officer directly to the fleet commander. A copy is retained on board in the files of the engineering department. An additional copy of the report may be provided to the type commander.



DIESEL ENGINE OPERATING RECORD - ALL SHIPS
NAVSEA 9231/2 (9-78) (FORMERLY NAVSEC 9410/2) S/N 0116-LF-092-3110

RETAIN 2 YEARS - THEN DISPOSE ACCORDING TO CURRENT DISPOSAL INSTRUCTIONS

U.S.S. | TIME ZONE DESCRIPTION | CLOCKS SET - BACK OR AHEAD HRS. MINUTES AT | LOCATION ☐ AT SEA ☐ IN PORT | DATE

CHECK ONE ☐ PROPULSION ☐ AUXILIARY ENGINE NO. ______ * Preferred to 30" Barometer

DISREGARD WHEN NOT REQUIRED

TIME	TACHOMETER	GENERATOR: ELECTRIC LOAD AMPS.	GENERATOR: ELECTRIC LOAD VOLTS	GENERATOR: TEMPERATURE AIR TO CLR.	GENERATOR: TEMPERATURE FWD. BRG.	GENERATOR: TEMPERATURE AFT. BRG.	TEMPERATURES: SALT WATER INJECTION	TEMPERATURES: SALT WATER OVER-BD.	TEMPERATURES: FRESH WATER TO ENG.	TEMPERATURES: FRESH WATER FROM ENG.	TEMPERATURES: FRESH WATER TO OIL CLR.	TEMPERATURES: LUBE OIL TO ENG.	TEMPERATURES: LUBE OIL FROM ENG.	TEMPERATURES: HOTTEST CYLINDER NO.	TEMPERATURES: HOTTEST CYLINDER TEMP.	TEMPERATURES: SCAV-ENGING AIR	PRESSURES: SEA WATER AT PUMP	PRESSURES: FRESH WATER TO ENG.	PRESSURES: LUBE OIL AT PUMP	PRESSURES: LUBE OIL AT ENG.	PRESSURES: FUEL OIL TO FLT.	PRESSURES: FUEL OIL FROM FLT.	PRESSURES: SCAV-ENGING AIR	PRESSURES: BACK PRESSURE (IN.)	PRESSURES: VACUUM* (IN.)	PRESSURES: CRANKCASE MANOMETER (IN.)	LUBE OIL SUMP (GAL.)	CLUTCH AND REDUCTION GEAR: L.O. IN CLUTCH (°F)	CLUTCH AND REDUCTION GEAR: L.O. OUT CLUTCH (°F)	CLUTCH AND REDUCTION GEAR: L.O. IN R. GEAR (°F)	CLUTCH AND REDUCTION GEAR: L.O. OUT R. GEAR (°F)	CLUTCH AND REDUCTION GEAR: L.O. OR AIR IN CLUTCH (°F)	CLUTCH AND REDUCTION GEAR: L.O. IN R. GEAR (P.S.I.)
0100																																	
0200																																	
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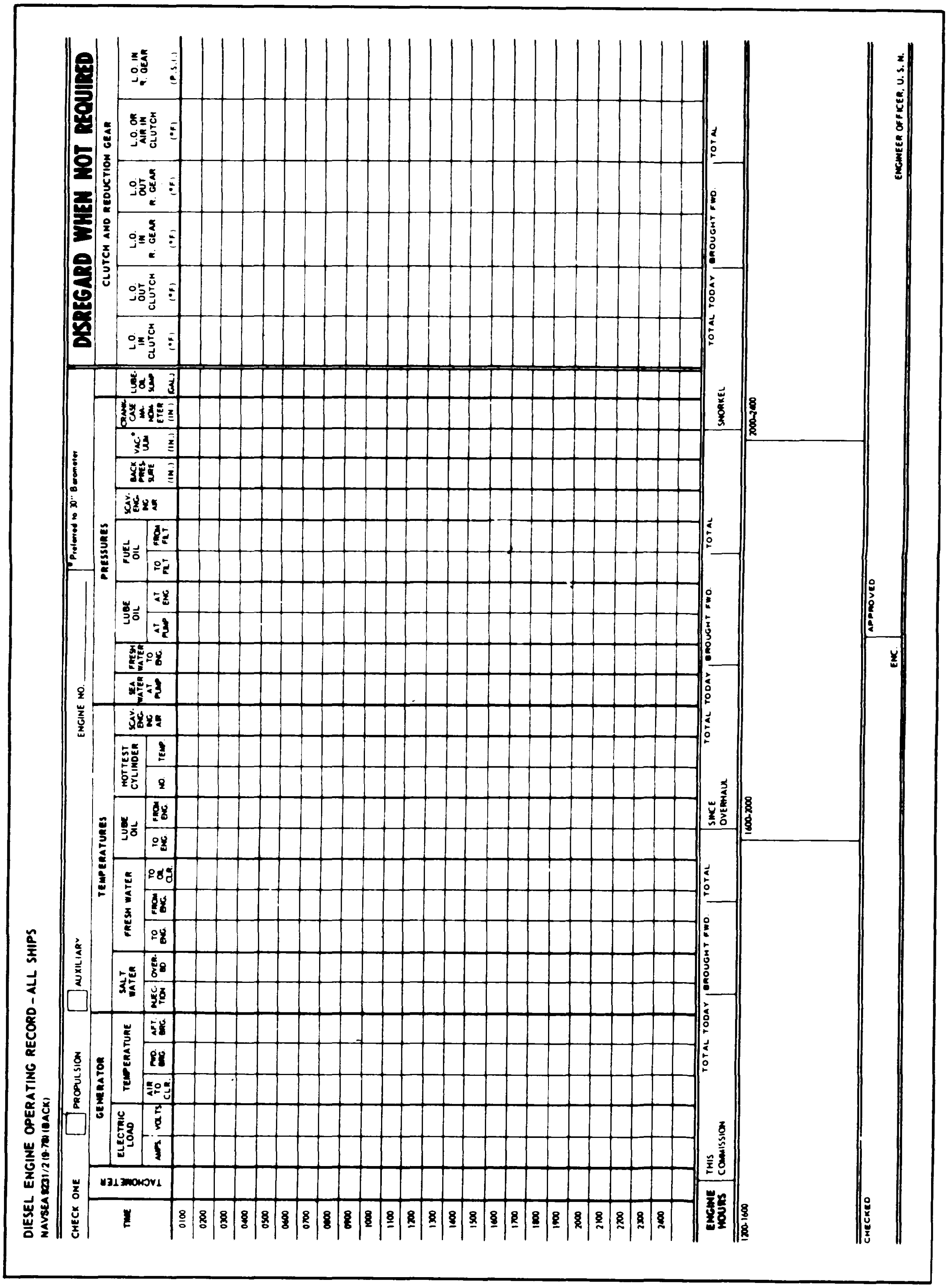
ENGINE HOURS	TOTAL TODAY	BROUGHT FWD.	TOTAL
THIS COMMISSION			
SINCE OVERHAUL			
SNORKEL			

0000-0400	0400-0800	0800-1200

A-6020

114.11.1

Figure 2-3.—Diesel Engine Operating Record—All ships.


DIESEL ENGINE OPERATING RECORD - ALL SHIPS
NAVSEA 9231/2 (9-78) (BACK)
CHECK ONE PROPULSION AUXILIARY
ENGINE NO.
* Preferred to 30" Barometer
DISREGARD WHEN NOT REQUIRED
TIME
TACHOMETER
GENERATOR
ELECTRIC LOAD
AMPS. VOLTS
TEMPERATURE
AIR TO CLR. FWD. BRG. AFT. BRG.
TEMPERATURES
SALT WATER
INJEC-TION OVER-BD
FRESH WATER
TO ENG. FROM ENG. TO OIL CLR.
LUBE OIL
TO ENG. FROM ENG.
HOTTEST CYLINDER
NO. TEMP.
SCAV. ENG. INC. AIR
PRESSURES
SEA WATER AT PUMP
FRESH WATER TO ENG.
LUBE OIL
AT PUMP AT ENG.
FUEL OIL
TO FLT. FROM FLT.
SCAV. ENG. INC. AIR
BACK PRES-SURE (IN.)
VAC-UUM* (IN.)
CRANK-CASE MA-NOM-ETER (IN.)
LUBE OIL SUMP (GAL.)
CLUTCH AND REDUCTION GEAR
L.O. IN CLUTCH (°F)
L.O. OUT CLUTCH (°F)
L.O. IN R. GEAR (°F)
L.O. OUT R. GEAR (°F)
L.O. OR AIR IN CLUTCH (°F)
L.O. IN R. GEAR (P.S.I.)
0100
0200
0300
0400
0500
0600
0700
0800
0900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
ENGINE HOURS
THIS COMMISSION
TOTAL TODAY
BROUGHT FWD
TOTAL
SINCE OVERHAUL
TOTAL TODAY
BROUGHT FWD
TOTAL
SNORKEL
TOTAL TODAY
BROUGHT FWD.
TOTAL
1200-1600
1600-2000
2000-2400
CHECKED
ENG.
APPROVED
ENGINEER OFFICER, U. S. N.

114.11.2

Figure 2-4.—Diesel Engine Operating Record—All ships (Back).

NAVSEA 9255/9 (1-79) (Front)
(Formerly NAVSEA 9510/1)

FUEL AND WATER REPORT

DATE ________

TO: COMMANDING OFFICER, USS ____________________

	FUEL (GALLONS)		LUBE OIL (GALLONS)	WATER (GALLONS)	
	BOILER FUEL	DIESEL FUEL	STORAGE TANKS	POTABLE	RESERVE FEED
ON HAND LAST REPORT					
RECEIVED (+)					
DISTILLED (+)					
EXPENDED (-)					
GAIN (+) LOSS (-) BY INVENTORY					
ON HAND THIS REPORT					
ON HAND %					

TRANSFERS/RECEIPTS (FUEL, LUBE OIL, OR WATER)
OIL
FROM ________ HRS TO ________ HRS AMOUNT (GAL) ________ SOURCE ____________
WATER
FROM ________ HRS TO ________ HRS AMOUNT (GAL) ________ SOURCE ____________

POTABLE WATER RECORD		
PERSONNEL ON BOARD	GALLONS USED PER PERSON	STANDARD

FEEDWATER CONSUMPTION	
NOT UNDERWAY (GALLONS PER HOUR)	UNDERWAY (GALLONS PER HOUR)

REMARKS:

98.165

Figure 2-5.—Fuel and Water Report (Front).

NAVSEA 9255/9 (1-79) (Back)

HOURS SINCE CLEANING				BOILER WATER CONDITIONS RECORD THE BOILER WATER TEST RESULTS IN THE DESIGNATED SPACES. RESULTS NOT WITHIN LIMITS MUST BE CIRCLED IN RED AND EXPLAINED IN REMARKS ON THE FRONT OF THIS REPORT.									
				LAST SAMPLE				RANGE OF RESULTS					
BLR NO.	FIRE-SIDE	WATER-SIDE (MECH)	WATER-SIDE (CHEM)	pH	COND.	PHOS-PHATE	CHLOR-IDE	pH	COND.	PHOS-PHATE	CHLOR-IDE	LAYUP CODE	TOTAL STEAMING HOURS
								MAX					
								MIN					
								MAX					
								MIN					
								MAX					
								MIN					
								MAX					
								MIN					
								MAX					
								MIN					
								MAX					
								MIN					
								MAX					
								MIN					
								MAX					
								MIN					

DEAERATED FEEDWATER CONDITIONS

SYSTEM	DISSOLVED OXYGEN (PPB)				SALINITY INDICATOR (EPM CHLORIDE)				pH			
	1	2	3	4	1	2	3	4	1	2	3	4
RANGE OF RESULTS	MAX				MAX				MAX			
	MIN				MIN				MIN			

BOILER WATER LIMITS:

	TYPE A	TYPE B
pH *	10.20 - 10.60	9.80 - 10.20
CONDUCTIVITY (μMHOS/CM)	600 MAX	400 MAX
PHOSPHATE (PPM)	50 - 120	25 - 60
CHLORIDE (EPM)	NOTE 1	NOTE 1

NOTE 1: SHOULD NOT NORMALLY EXCEED 1.00 EPM (CONTAMINATION NOT OCCURRING)

FEEDWATER LIMITS:

	ALL SHIPS
DISSOLVED OXYGEN (PPB)	15 PPB BY METER, 15 PPB BY CHEMICAL TEST
SALINITY (EPM CHLORIDE)	0.02
pH	8.60 - 9.00

BOILER LAYUP

DRY
- DES DESICCANT
- HTD HEATED AIR

WET
- STM 150 PSI STEAM (SHIP)
- STS 150 PSI STEAM (SHORE)
- NIT NITROGEN
- DFT HOT DFW FILL
- HYD HYDRAZINE

PREPARED BY: (OIL KING)	REVIEWED: (MPA)	REVIEWED: (ENGINEER OFFICER)

98.165

Figure 2-6.—Fuel and Water Report (Back).

MONTHLY SUMMARY OF FUEL INVENTORY AND STEAMING HOURS REPORT
LANTFLT 3100/1 (Rev. 7/73) *0103-LF-631-0011*

CINCLANTFLT REPORT 3100-4
(No letter of transmittal required. Submit by 3rd 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 CDR 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, STRIPPING, CONTAMINATION (–)				
TOTAL MONTHLY DELIVERIES TO SHIP, HELO, ETC. (–)				
FUEL CONSUMED UNDERWAY (–)				
FUEL CONSUMED NOT UNDERWAY (–)				
FUEL CONSUMED FOR BOATS, AUX, ETC. (–)				
FUEL INVENTORY ON BOARD END OF MONTH (Bal)				

	STEAMING UNDERWAY	STEAMING NOT UNDERWAY	NOT UNDERWAY COLD IRON	TOTAL HOURS FOR MONTH
HOURS				

FUEL RECEIPTS - DETAIL FROM ISSUING SHIP OR SHORE ACTIVITY				FUEL DELIVERIES - DETAIL AND DOCUMENT NUMBERS			
Date	From	Type	Gallons	Date	To	Type	Gallons

SUBMITTED	RECEIPTS/DELIVERIES VERIFIED	FORWARDED APPROVED
CHIEF ENGINEER	SUPPLY OFFICER	COMMANDING OFFICER

147.169

Figure 2-7.—Monthly Summary of Fuel and Steaming Hours Report, CINCLANT FLT Report 3100-4.

The Monthly Summary includes the ship's fuel receipts data, fuel consumption and steaming hours necessary to establish monthly financial obligations, and fuel requirements data for budget justification. It also generates management reports for fuel receipts by operational and type commanders. This report includes all fuel data as of 2400 hours of the last day of the month and must be forwarded within 5 days of completion of the reporting month. Fleet Commander Instructions contain detailed instructions for completing the forms, as well as the 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 underway and 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. The mathematical accuracy of the computations must be observed when the report is being prepared to avoid the necessity of resubmitting a corrected form later.

Disposal of Engineering Records and Reports

Before any of the engineering department records are destroyed, the *Disposal of Navy and Marine Corps Records,* USN and USNS Vessels, SECNAVINST 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 the permanent records which must be kept, and the 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 such case, copies (preferably photostatic) of such sheets or parts of these records that are sent away from the ship are certified by the engineer officer as being true copies for the ship's files.

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 are retained. If a ship is scrapped, the current books are forwarded to the nearest Naval Records Management Center.

All reports forwarded to, and received from, NAVSEA or other superior command may be destroyed when 2 years old, if they are no longer required.

Only those reports which are required or serve a specified purpose should be maintained on board ship. However, any report or record which may assist personnel in scheduling or making repairs and which will supply personnel with information which is not contained in publications or manuals should also be kept on board.

Trend and Spectrographic Analysis

Two types of inspections and tests that can be used to "spot" impending trouble in an internal combustion engine before it can seriously affect its operation are called trend and spectrographic analyses. We will now discuss and explain their importance and use in detecting problems in internal combustion engines.

ENGINE TREND ANALYSIS.—Preventive maintenance receives a great deal of attention from everyone in the field of diesel engine operation, since the idea of letting an engine run as long as it will run and fixing it only after a breakdown occurs is not only foolish, but extremely costly. On the other hand, it would be just as foolish to be constantly tearing down an engine for inspection. It is a known fact that vital parts of an engine last longer and operate better if they are not tampered with unnecessarily. Therefore an attempt must be made to find a happy medium between these two forms of maintenance.

One way is to determine the condition of an engine is by monitoring its operation. This is done by regularly obtaining certain engine operating data and by studying, and analyzing, and comparing it with previous data. This information is then reduced to a form which all engineering personnel can interpret and, based on the findings, decide whether or not the engine needs to be overhauled in order to ward off serious and costly damage or just be temporarily shut down for some simple maintenance.

The key to utilizing engine performance data as a tool is to make graphs from the data which show at a glance the signs of impending distress. Analysis of this graphical display is commonly called trend analysis.

In order to get a good indication of the engine condition, the following specific items are recorded.

1. Cylinder compression pressures.
2. Cylinder firing pressures.
3. Fuel pump rack or governor power piston position.
4. Cylinder exhaust temperature.
5. Crankcase vacuum.
6. Lubricating oil pressure at engine inlet or upper header.
7. Manifold air or scavenging air pressure.

To produce meaningful graphs, all data must be plotted under the same conditions, and be obtained at some readily duplicated condition. It is not important that the engine be under full load at full speed when taking data, but it is important that all data be obtained under similar conditions. For example:

1. Always obtain data from generator sets at 80% load and 100% speed.
2. Always obtain data from propulsion engines; for example, standard or full.

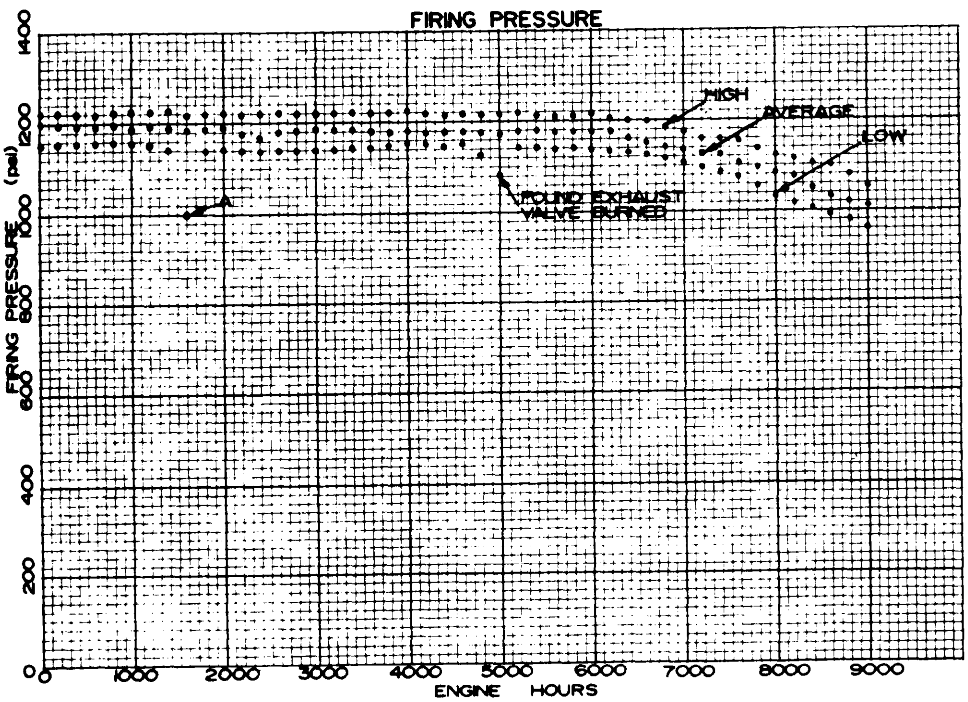
Data need not be plotted daily. In most cases, a set of readings should be plotted every 200 hours of operation. In some cases it may be prudent to repeat a set of readings when a large change in operating characteristics has apparently occurred.

The first step in preparing the graphs for trend analysis is to collect the data. This is done by observing and recording the above items with the engine operated at a selected type of condition for a sufficient time, prior to taking data, to allow pressures and temperatures to stabilize. (It can be assumed that conditions have stabilized when lube oil and freshwater temperatures are within ± 5° of the normal operating temperatures.

These data are then plotted on 10 × 10 lines per inch graph paper as shown on the examples (figures 2-8 through 2-15). For convenience, the first points are located at zero time for an engine that has just been overhauled or at the number of hours on the engine since the last overhaul (0, 400, 1000, 1600 hours, etc.). The first point for lube oil consumption occurs at 200 engine hours. This is done because it is easier to start with a full engine sump and monitor the amount of oil added each 200 hours to obtain the consumption rate. Once the initial points have been plotted, all that is required is to record and plot the same information each 200 hours and observe the trends that develop. (NOTE: remember to always take data under the same controlled conditions!)

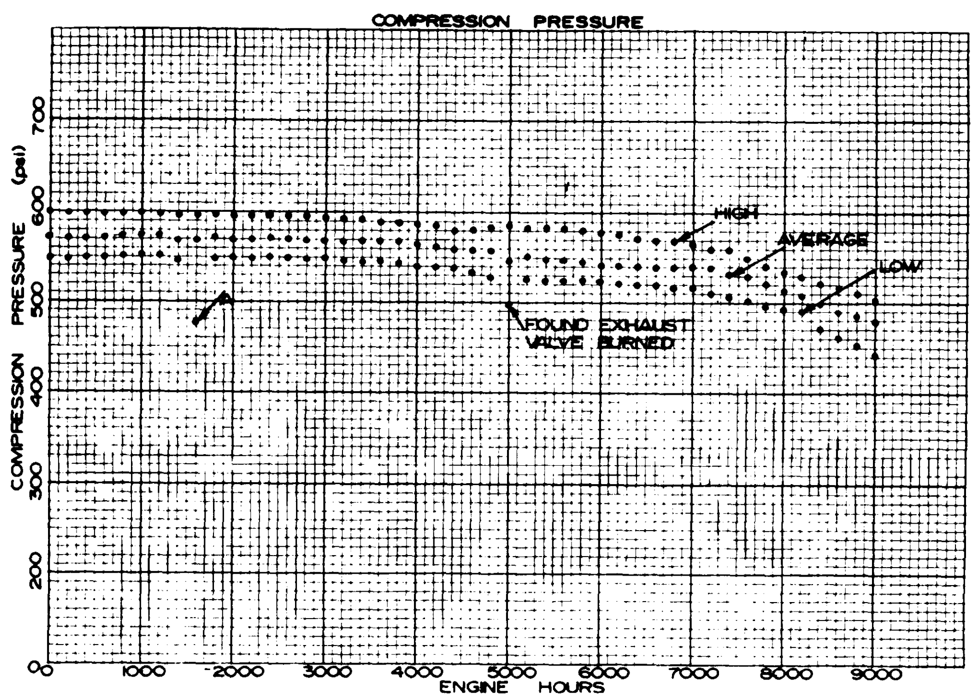
A close look at the sample graphs will reveal how they can be used to determine engine condition. For purposes of illustration, the ideal trend of each graphed value is shown for a hypothetical engine. Unfortunately, the Navy does not have too many ideal engines so some samples of problem indications that may be expected are also included.

On figures 2-8 and 2-9, a high, average, and low value is plotted for both firing and compression pressures. Under normal conditions these curves will remain flat until the engine is approaching the time of overhaul, then the curves will start to fall off. The high and low firing pressures will remain at about ± 50 psi (100 psi spread) from the average firing pressure for a well-balanced engine. If you look at figure 2-8 you can see that a decided drop in firing pressure has occurred at 1600 hours (point A). This failure in the compressing pressures indicates that the rings are either sticking, broken, or beginning to wear; that the valves are not functioning properly; or that the liner is beginning to score or possibly that a piston has cracked. Remember that any change in a curve (beyond normal limits) indicates that immediate attention is required. At this point, it should be pointed out that more than one indicator will usually reveal the same distress signal. Therefore, before any corrective action is taken, it is best to make a study of other curves to deny or confirm the problem. In this case check the lube oil consumption, crankcase vacuum, and exhaust temperature curves. In figures 2-9, 2-10, and 2-15 the typical indications for this problem



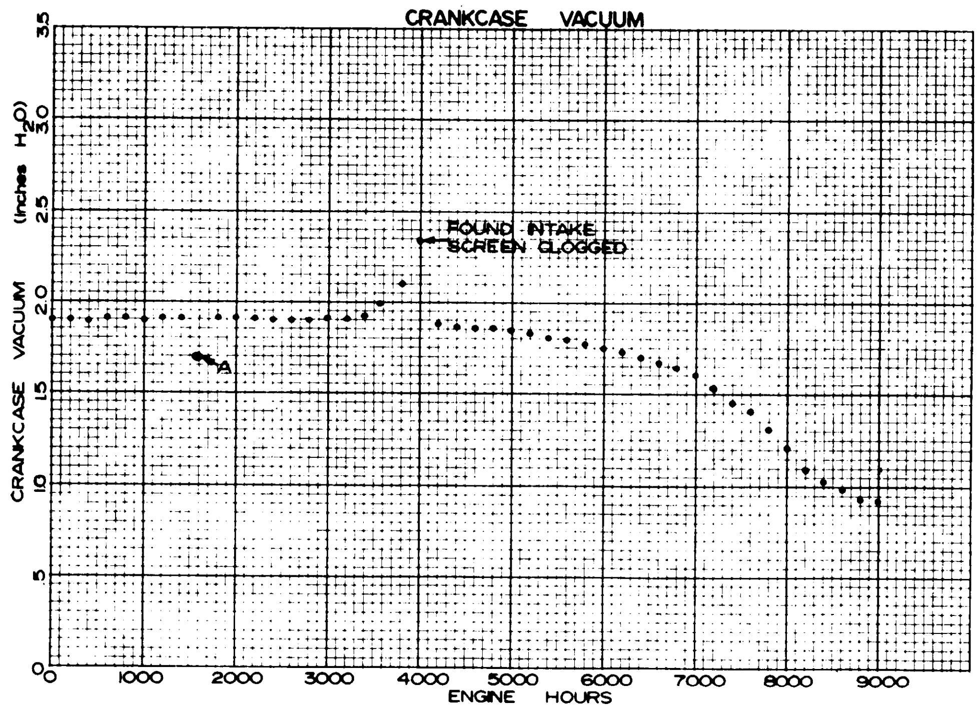
121.39

Figure 2-8.— Firing Pressure Graph.



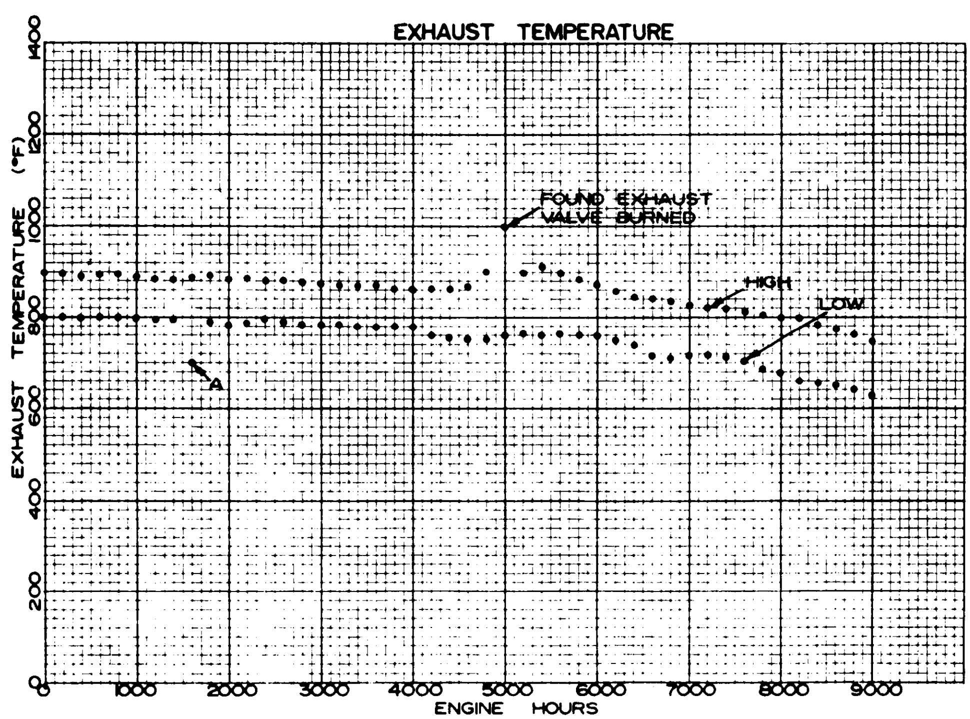
121.40

Figure 2-9.—Compression Pressure Graph.



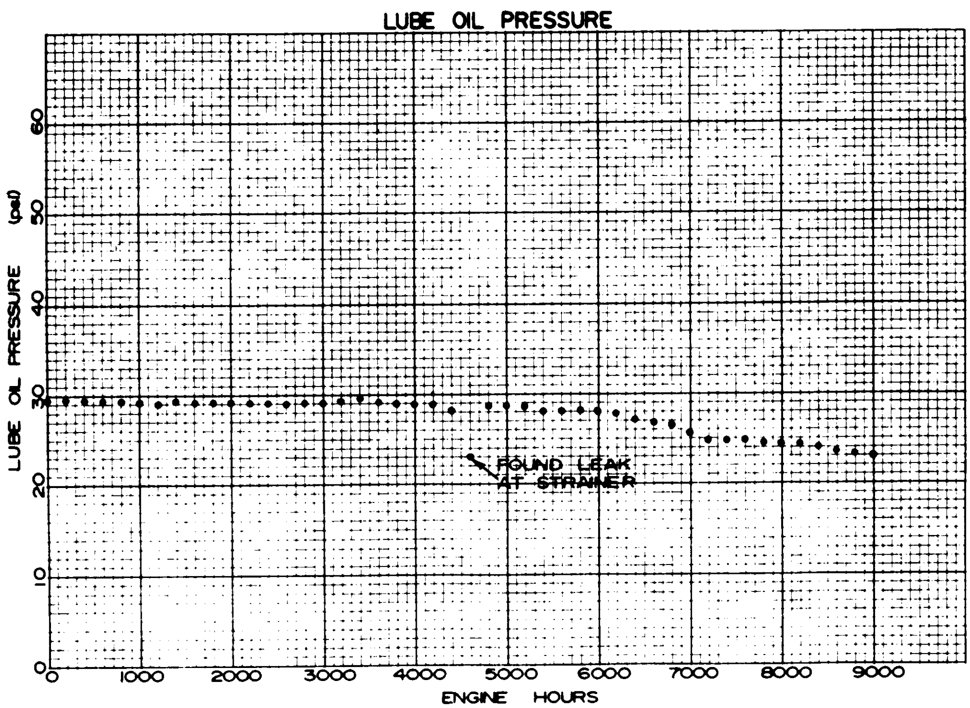
121.41

Figure 2-10.—Crankcase Vacuum Graph.



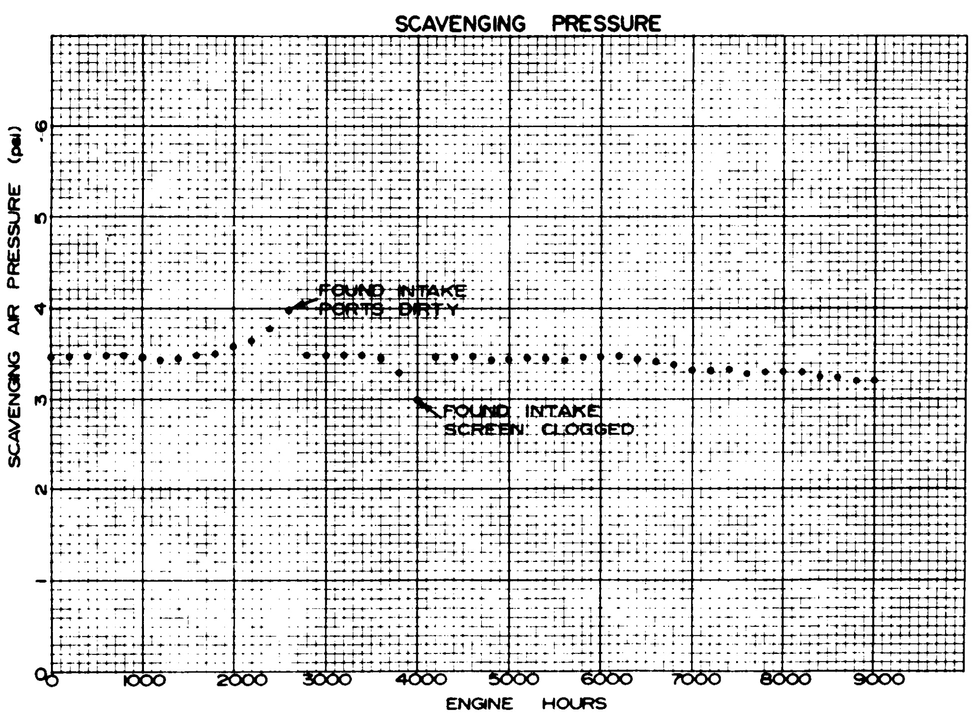
121.42

Figure 2-11.—Exhaust Temperature Graph.



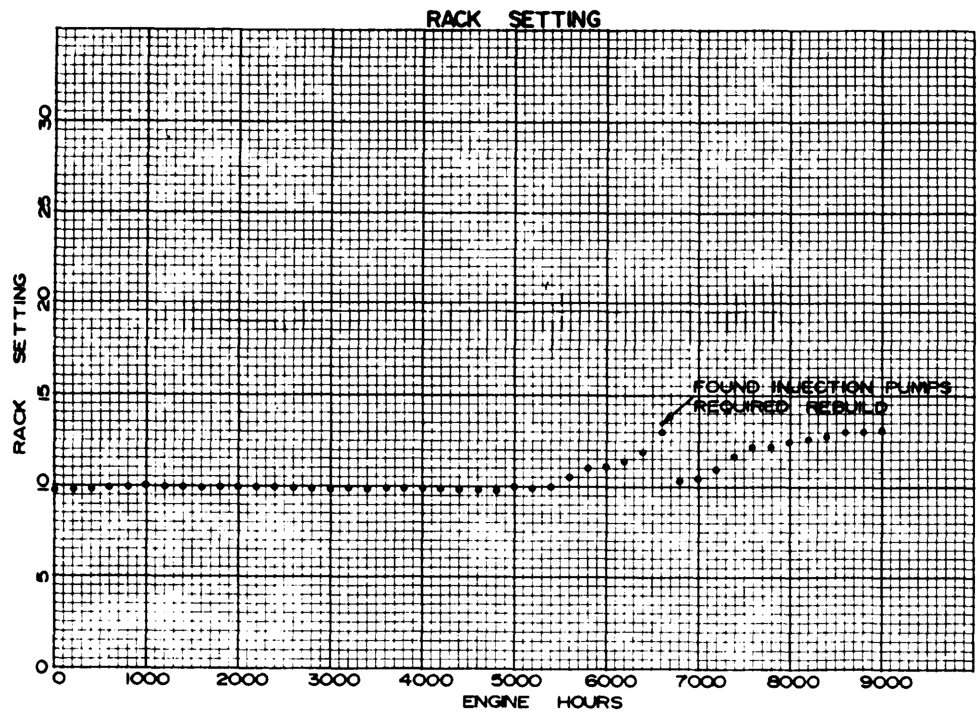
121.43

Figure 2-12.—Lube Oil Pressure Graph.



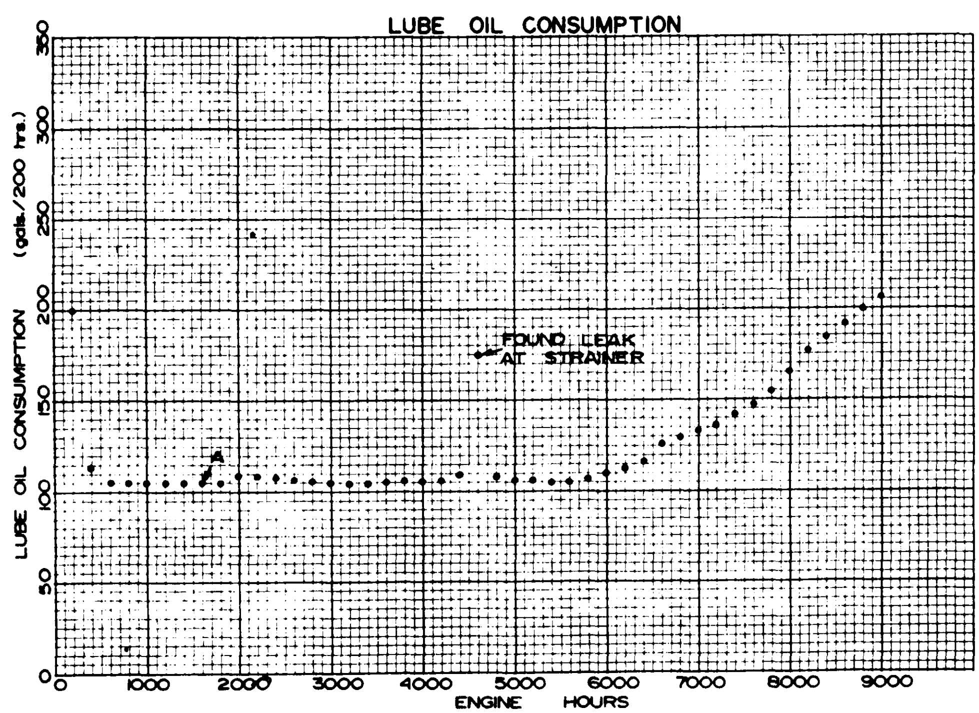
121.44

Figure 2-13.—Scavenging Pressure Graph.



121.45

Figure 2-14.—Rack Setting Graph.



121.46

Figure 2-15.—Lube Oil Consumption Graph.

are marked as point A. All indications point to a definite internal problem in one cylinder. No rise in lube oil consumption is indicated (point A on figure 2-15) because a slightly worn set of rings or liner probably would not cause a measurable increase in lube oil consumption. The logs should now be consulted to find the problem cylinder and initiate appropriate repairs.

If only firing pressures and exhaust temperature are low, the fuel system should be checked on the problem cylinder.

The crankcase vacuum graph (figure 2-10) indicates ring, piston, or liner condition. As long as everything is normal, this curve will also be flat. A cracked piston, worn rings, or liner will increase blow-by, causing decreased crankcase vacuum. If crankcase vacuum decreases with no change in other indicators, the crankcase scavenging system should be checked for proper operation. An increase in crankcase vacuum may be caused by a clogged intake screen.

The exhaust temperature graph (figure 2-11) indicates general cylinder conditions and engine balance, although this item is not necessarily a definite indication of trouble itself. Any abnormal temperature with no accompanying change in the various other indicators can usually be attributed to a faulty pyrometer. The pyrometer in question should then be carefully inspected and tested before any other inspections or adjustments are accomplished.

The lube oil pressure graph (figure 2-12) indicates the engine bearing condition, lube oil pump condition, piping conditions, by-pass relief valve conditions, etc. Lube oil pressure obtained at the upper header of Fairbanks Morse opposed piston engines is particularly useful in monitoring the condition of the internal portion of the lube oil system.

The manifold pressure graph (figure 2-13) indicates the condition of the scavenging system. Increasing air box pressures indicate port clogging, while reduced air box pressures indicate some abnormality in the air intake systems, blower, or turbocharger. Both of these cases require immediate attention.

The fuel rack or governor power piston position graph (figure 2-14) indicates the general condition of the fuel system. Increased rack settings for a given power output indicate fuel pump deterioration or a decrease in engine combustion efficiency.

The lubrication oil consumption graph (figure 2-15) is for the lubricating oil consumption in gallons per 200 hours operation. It should be noted that the values on this curve are initially very high. They decrease and then remain nearly constant until the engine is approaching its overhaul time. The initial high consumption is due to unseated piston rings. As rings become seated, the consumption will decrease to a normal value and remain nearly constant until the rings or liners begin to wear. Any significant increase in lube oil consumption must be carefully evaluated to determine if the oil is really being consumed in the engine or is being lost because of external leaks. Too many times an engine is assumed to be at fault when lube oil is really being lost due to leakage.

Review of figures 2-8 through 2-15 will also indicate other problems that are not discussed in this text. Each sample problem is marked on the various graphs at the appropriate engine hours so a study of the samples can be made.

In conclusion, operational graphs show the condition of the engine. They show what is happening, what needs to be done, and what has to be planned for in advance. The life expectancy of vital parts can be determined from these curves, and the parts can be renewed before they reach the point of failure.

The trend analysis program must be followed closely, especially during the initial period of the program when care must be taken to ensure that the data gathered are meaningful. However, if the condition of any particular engine indicates that an overhaul is required to maintain it operational, this should be accomplished at the earliest possible time.

ENGINE LUBE OIL ANALYSIS.—Spectrometric oil analysis is another valuable tool which can be used to determine the extent of accelerated wear in internal combustion engines and other machinery which use closed lube oil or hydraulic oil systems. By the use of spectrometric oil analysis, the accelerated wear in machinery can be detected without disassembling the equipment long before there is any other indication of immediate trouble. As a result of this type of analysis, skilled maintenance personnel have been able to pinpoint wear areas early, and to take corrective and preventive maintenance action during an emergency or on a pre-planned basis as determined by the type of accelerated wear detected. By replacing worn out minor parts a major failure can be prevented, and the requirement for costly parts replacements of complete overhaul of the equipment can be eliminated.

Ships shall maintain accurate records of operating hours since major overhauls, oil changes, and samplings in order to provide the testing facility with the information requested in the sampling kit. (COMNAVSURFLANT uses the services of the Charleston Naval Shipyard and COMNAVSURFPAC uses Intermediate Maintenance Activities (IMA) for analyzing oil samples from machinery employing closed lube oil/hydraulic systems.) In addition, a record of conditions found and repairs effected as a result of inspections conducted following recommendations of the laboratory must also be maintained.

When the shipyard or IMA laboratory receives the oil sample, a physical test and a spectrometric analysis are performed. The physical test consists of the following:

1. All samples are tested for fuel dilution, and a report is provided to all concerned by percent volume as per requirements of ASTM D92057.

2. All samples are tested for solids by centrifuge to show the amount of suspended particles separately from precipitated solids. The test must differentiate between those fine particles suspended by the active compounds in the oil and those that can settle out of the oil spontaneously to give a ratio of colloidal/precipitated solids.

3. Allowable "use limits" are tested and recorded.

When the physical test is completed the shipyard/IMAs should make a spectrometric analysis of each used oil sample, then record and report to all concerned the concentrations of the following elements in parts per million (ppm). (See figure 2-16.)

Iron (Fe)	Nickel (Ni)	*Sodium (Na)
Lead (Pb)	Silver (Ag)	Phosphorus (P)
Copper (Cu)	Tin (Sn)	Zinc (Zn)
Chromium (Cr)	Silicon (Si)	Calcium (Ca)
Aluminum (Al)	Boron (B)	Barium (Ba)

*Only when evidence of water is present.

Testing will be done for all the above elements.

The sensitivity and reliability of the equipment used for the test will be such that the standard deviation obtained in the analysis for each specified element must not exceed the appropriate value shown in figure 2-16.

Additional information on trend analysis and oil spectrometric analysis is contained in COMNAVSURFLANTINST 9000.1 or COMNAVSURFPACINST 4700.1A.

Element Concentration In

Standard Reference Specimen (Range in PPM)	Standard Deviation (Maximum in PPM)
3 - 9	1.5
10 - 19	2
20 - 49	3
50 - 99	5
100 - 199	8
200 - 500	15

Figure 2-16.—Element Concentrations.

MAINTENANCE AND REPAIR RESPONSIBILITIES

In order to fulfill your maintenance and repair responsibilities along with your administrative and supervisory responsibilities you must plan your work ahead of time.

You must determine all the work that must be done and prepare a schedule to ensure that it is done. You must also keep your schedule flexible enough to allow unexpected maintenance and repair work to be done whenever the need for such work arises.

Review the Maintenance and Material Management (3-M) Manual, OPNAVINST 4790.4, it will make your planning and scheduling considerably easier.

Materials and Repair Parts

The responsibility for maintaining adequate stocks of engineroom 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 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. Namely You!

Basic information on supply matters is given in *Military Requirements for PO 3 & 2*, NAVEDTRA 10056 (current edition), *Military Requirements for PO 1* & *C*, NAVEDTRA 10057 (current edition), and OPNAVINST 4790.4, volume II.

Identification of Repair Parts and Materials

Identification of repair parts and materials is not usually a 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 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 either have to use your own judgment or do 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.

The fact that materials and repair parts are not specified in the instructions accompanying a job does not mean that you are free to use your own judgment in selecting parts and materials to accomplish a job. Instead, it usually means that you must know where to look for information on the type of material or repair parts needed, then locate and requisition them in order to complete the assigned job.

There are several shipboard sources of information that will be useful to you in identifying the equipment and/or the repair parts needed. They include the Coordinated Shipboard Allowance List (COSAL); nameplates on the equipment; manufacturer's technical manuals; and ships' plans, blueprints, and other drawings.

COORDINATED SHIPBOARD ALLOWANCE LIST (COSAL).—The COSAL is both a technical and a supply document prepared for an individual ship. It lists the equipment or components required for the ship's operation; the repair parts and special tools required, the overhaul and repair equipment, and the miscellaneous portable items necessary for the care and upkeep of the ship.

For your purpose, the COSAL is the basic source of information on repair parts and materials needed for a job. A COSAL gives you information on such items as the noun name of a system (engine, pump, ejector, etc.), the manufacturer's name and the I.D. number (General Motors Corporation #3255), the technical manual number for the system, the manufacturer's drawing numbers, and the Allowance Parts List (APL) numbers for related systems (governor's, starters, transmissions, etc.). In addition, COSAL provides specific information about National Stock numbers (NSNs), units of issue, costs, and the number of items needed. It may also include lists of part numbers and Federal Stock Numbers (FSNs) for crossover checks.

To request materials and repair parts from the supply department aboard ship, you must fill out and submit a NAVSUP Form 1250, a single 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. However, if all the information you have available is a manufacturer's part number, then you must also fill out and submit, along with the NAVSUP Form 1250, a DD-1348-6 Form, NON-NSN REQUISITION. For information on how to fill out these supply forms, review *Military Requirements for PO 3 & 2,* volume II of OPNAVINST 4790.4, or ask your ship's supply personnel for assistance.

Whenever you find it necessary to request materials or repair parts, remember two things:

1. If at all possible, find the correct NSN for each item requested. All materials now in the supply system have been assigned an NSN, and you should be able to locate them by using the COSAL and the other sources of information available to you such as the following:

a. NAMEPLATES on equipment supply information regarding the characteristics of the equipment. Nameplate data seldom, if ever, include 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.

b. 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.

c. 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 lately, 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 COSAL to be sure that any changes made since the original installation have been noted on the drawings.

2. Work informally with the supply department personnel who are actually responsible for identifying and requesting material. You have the technical knowledge, and you know what you need. If you cannot find the correct stock number, however, your job is to give enough standard identification information, such as manufacturer part numbers, and Allowance Parts List/Component Identification Description (APL/CID) numbers, 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.

SHIP EQUIPMENT CONFIGURATION ACCOUNTING SYSTEM (SECAS).—When the structure or composition of either the ship or a particular system or equipment on board a ship is modified, this modification must be documented. This action will ensure proper accounting of configuration changes, and will help improve supply and maintenance support technical manuals, PMS coverage, updated COSAL, etc., to your ship. SECAS is the designated system responsible for maintaining the configuration status reported by your ship.

Although the responsibility for identifying and reporting these changes rests at all levels of the command, the work center supervisor is responsible for ensuring that the proper documentation is completed and processed as described in volume II of OPNAVINST 4790.4.

OPNAV Form 4790/CK, Ship's Configuration Change Form, is used to report configuration changes at the individual equipment level.

SHIP-TO-SHOP WORK.—Many repair jobs are designated by the ship or approved by the repair activity as "ship-to-shop" jobs. In this type of job, the 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 ship's force will disassemble the pump and remove the shaft. Then the shaft and any necessary blueprints or technical manuals are delivered to the designated shop of the repair activity. After the shaft has been repaired, or a new one has been made, it is picked up and brought back to the ship by the ship's force. The pump is reassembled, inspected, and tested by the ship's force to make sure that it is operating satisfactorily.

An important thing to remember is that while the repair facility is responsible for ensuring that its personnel repair or manufacture this shaft to the manufacturer's specifications, perform all tests required by Quality Assurance (QA), and fill out properly all the required forms, it is your responsibility to witness any test required by QA, to monitor the status of the job at all times, and to reassemble and test operate the equipment properly, so that the end results will produce a reliable operating piece of equipment.

EQUIPMENT TESTS.—As an EN1 or ENC, you have the responsibility for scheduling and performing various tests on your equipment. The purpose of those tests is to determine how your equipment is performing and if there are any equipment malfunctions. These tests are performed at various times, such as (1) before going to the shipyard for overhaul, (2) after post deployment, (3) during a tender availability, or (4) as required by PMS. The tests are performed by the ship's force, IMA personnel, shipyard personnel, or by an inspection team (such as the Board of Inspection and Survey (INSURV Board)). Detailed types of inspections are described in COMNAVSURFLANT Inst. 9000.1 or COMNAVSURFPAC Inst. 4700.1A.

Scheduling Work

Careful planning is required to keep up with all auxiliary maintenance and repair work in the enginerooms. You should already have in your work center the necessary items which can help you in scheduling your work. These items are (1) the Quarterly PMS Schedule, which is the visual display of your work center's PMS requirements for a specific 3-month period; (2) the weekly schedule (taken from the quarterly schedule), which displays all your work center's PMS schedule for completion in a given week; and (3) the Maintenance Data Collection Subsystem (MDCS) forms, such as the OPNAV 4790-2K, OPNAV 4790-2L, and OPNAV 4790-2Q. Of these, OPNAV Form 4790.2K is used to show completion of specific PMS requirements; to request repair of equipment or services from IMAs or shipyards; or can be used to describe equipment malfunctions. OPNAV Form 4790/2L is a supplemental form which you use to provide amplifying information relating to a maintenance action described on a corresponding 4790/2K. The OPNAV 4790/2L may also be used to list: Multiple item serial numbers and locations for which identical maintenance requirements exist from an outside activity; and Drawings and sketches.

OPNAV Form 4790/2Q is an automated work request produced by an IMA with computer capabilities. The "2Q" is produced from the original 4790/2K which is in your Current Ships Maintenance Project (CSMP) suspense file. For more detailed information about these forms and schedules, and how to fill them out, review OPNAVINST 4790.4, volumes I and II.

Some of the proven uses you should follow when scheduling maintenance and repair work are listed below:

1. Size up each job before you let anyone start working on it. Check the applicable Maintenance Requirement Cards (MRCs) so that you will know exactly what needs to be done. Also, check all applicable drawings and manufacturer's technical manuals.

2. Check on materials before you start. Be sure that all required materials are available before your personnel 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 availability of materials before a job is actually started. An inoperable piece of machinery may be useless, but it can become a nuisance and a safety hazard if it is spread around the engineroom in bits and pieces while you wait for the arrival of repair parts or materials.

3. Check the priority of the job and that of all other work that needs to be done.

4. When assigning work, carefully consider the capabilities and experience of your personnel. As a rule, the more complicated jobs should be given to the more skilled and more experienced

people. When possible, however, less experienced people should be given difficult work to do under supervision so that they may acquire skill in such jobs.

Be sure that the person who is going to do a job is given as much information as necessary. An experienced person may need only a drawing and a general statement concerning the nature of the job. A less experienced person 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 all necessary records and reports have been prepared. These job inspections serve at least two very important purposes: first, they are needed to make sure that the work has been properly performed; and second, they provide for an evaluation of 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 any defects or flaws, be sure to explain 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 personnel, and the amount of material that will be required for specific 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 people 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 ultimately 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 availability 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. Although these factors are also important in the routine scheduling of maintenance and repair work, they are particularly important when estimates of time that may affect the operational schedule of the ship are made.

If part of the job must be done by other shops, you must consider not only the time actually required by these shops but also time that may be lost if one of them holds up your work, and the time spent to transport the material between shops. 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.

Consider all the interruptions that might cause delay, over and above the time required for the work itself. Such things as drills, inspections, field days, and working parties can have quite an effect on the number of people who will be available to work on the job at any given time.

Estimating the number of personnel 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 people available but also the maximum number of people who can work EFFECTIVELY on a job or on part of the job at the same time. Doubling the number of personnel will not cut the time in half; instead, it will result in confusion and aimless milling around.

The best way to estimate the time and the number of personnel needed to do a job 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 personnel 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 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 you have reached the E-5 or E-6 level, you have acquired many skills and a large amount of theoretical knowledge. Among other things, you have learned 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; 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 knowledge you must have in order to qualify as an expert Engineman. But even a very wide range of abilities and an extensive theoretical knowledge will not, in themselves, guarantee your success as an instructor.

TRAINING RESPONSIBILITIES

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 trainees.

You will find excellent general information on how to plan, carry out, and evaluate an instructional program in *Military Requirements for Petty Officer 3 & 2*, NAVEDTRA 10056 (current edition) and in *Military Requirements for Petty Officer 1 & C*, NAVEDTRA 10057 (current edition). 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 and auxiliary personnel and some of the ways in which you can overcome or minimize these difficulties.

What kinds of things cause special problems in the training of engineroom personnel? For one thing, the interrelationship of propulsion plant operations. Each person must be trained to perform not only as an individual but also as a member of a team. Take for instance the duties of the watchstanders. They are very closely related, and the actions taken by one person depend in some way upon the actions taken by other persons. From a long-range point of view, however, the teamwork required for engineroom operations can actually be turned to a training advantage. As a person is being trained for one specific duty, he must of necessity be learning something about the other duties. As a rule, therefore, the first part of a person's engineroom training may take quite a while, but the last part will be comparatively fast.

The procedures for training a new person in engineroom operations vary considerably, depending upon such factors as the ship's steaming schedule, the condition of the engineroom machinery, the number of experienced personnel available to assist in the training, and the amount of time that can be devoted to the training. In general, however, you will probably begin to train a person to act as messenger. Then before the trainee is assigned to any actual duty, of course, the trainee should be introduced to the engineroom and become familiar with the location of all machinery, equipment, piping, and valves. The trainee must also be instructed in certain basic safety precautions and be specifically warned about the dangers of turning valve wheels or tampering with machinery. "IF IN DOUBT, ASK QUESTIONS!" is a pretty good rule for any new person in the engineroom to follow.

A person ready to be trained in the duties of messenger should be shown all the gages that are in use, told about what the gages indicate and shown how to take readings. The reason why the readings are important should be explained. The trainee should understand exactly how often each gage must be read and how to make accurate entries in the engineroom log. When you are sure the trainee understands everything about gages, teach the trainee how to check lube oil levels and how to clean metal edge type filters and basket-type strainers.

For a while you will have to keep a close watch on the trainee's performance of these duties. When the trainee becomes proficient in the duties of messenger, start the training in throttleman's duties, First, let the trainee observe the throttleman. Then, if conditions permit, let the trainee start and secure machinery.

As far as manual skills are concerned, the throttleman's job is probably easier than the messenger's job. But the throttle watch requires the utmost vigilance and reliability, and a new person will have a lot to learn before being trusted to stand the throttle watch alone. Personnel should always be started out under the supervision of an experienced throttleman, and should remain under this supervision until the petty officer in charge of the engineroom is fully satisfied that the trainee is completely qualified for this duty.

In training engineroom personnel who have not had previous engineroom experience, remember than an engineroom can be a complicated and confusing place to someone who walks into it for the first time. A lot of equipment is crammed into a small space, and a lot of complex actions are going on at once. When training new personnel, try to think back to the time when you first went into an engineroom. What aspects of engineroom operations were most confusing to you at first? What kind of training would have made your learning easier and faster? By analyzing your own early experience and reactions, you get a bearing on what a new person may be experiencing and you may be able to provide more effective training.

When you are training new personnel, remember that they vary widely in their methods of learning and in their rates of learning. Some people will learn most effectively if you give them an overall view of main engine operations, including a certain amount of theory, before going into the details of the hardware and the manual operations. Others will learn most effectively if they are taught some manual skills before getting too much involved with theory. Some people learn manual skills rapidly but take a long time to absorb the theory; for others, the reverse is true. And, of course, some people learn everything slowly. Some trainees benefit from patient, almost endless repetition of information; others may become bored and restless if you go over the same point just once too often. The important thing to remember is that your training efforts will be most successful if you are able to observe and allow for the individual differences that are bound to exist. Closely related to this point is another: Don't make snap judgments about people's abilities until they have had a chance to DEMONSTRATE them. You may turn out to be very wrong if you make snap judgments on the basis of a general impression, such as appearance, or the rate at which they learn when they first come into the engineroom.

When training personnel who have already had some engineroom experience but who have been on some other type ship, you may find that a certain amount of retraining is needed before the individual can qualify as an engineroom watchstander on your ship. No two enginerooms are precisely alike in all details, and no two main engines that appear to be identical behave in precisely the same way under all conditions. Each engine has its own individuality, and operating personnel must adjust to the engine in order to obtain the best results. Practically all Enginemen learn this sooner or later; you can speed up the learning process by encouraging engineroom personnel to notice and to discuss differences between engines.

Because of the necessity for strict observance of safety precautions, all engineroom operational training must be rigidly controlled and supervised. On-the-job training is necessary if an individual is to acquire the actual skills needed for main engine operation; however, the person must not be allowed to learn by trial and error, since errors could be too dangerous and too costly. Safety precautions should be taught from the very beginning and should be emphasized constantly throughout the training program.

TRAINING PROGRAMS

As an EN1 or ENC you are required to establish or maintain a training program for your work center personnel. In this program you are required to teach the proper methods of equipment operation, repair, and safety. You should use all the materials available to you including teaching aids (manufacturer's technical manuals, instructions, or rate training manuals). In addition, you should know what schools are available to your workers and should try to get quotas for them (i.e., EN "A" or "C", or A/C&R).

In recent years, one of the best ways to check on how well personnel retain the information being taught in your training program has been the use of the Personnel Qualification Standard PQS).

A PQS is a written list of knowledge and skills that are required to qualify for a specific watchstation, maintain a specific equipment or system, or perform as a team member within an assigned unit. The PQS program is a method for qualifying personnel to perform their assigned duties.

Most Standards are divided into four sections: Fundamentals, Systems, Watchstations, and a Qualification Card. The Fundamentals section contains the facts, principles, and fundamentals concerning the subject for which a person is qualifying. The Systems section deals with the major working parts of the installation, organization, or equipment with which the PQS is concerned. The Watchstation section defines the actual duties, assignments, and responsibilities needed for qualification. The Qualification Card has questions that match those in the Watchstation section and provides a space for the supervisor's or the qualifying officer's signature.

Not only your work center personnel must qualify under PQS but also you must qualify on all equipment under your control, in addition to the Maintenance and Material Management (3-M) System, and General Damage Control. Let's look at one of the requirements for an EN1 or ENC under PQS and the Engineman Occupational Standards, NAVPERS 18068-D. The requirement calls for you to supervise a damage control party. As an engineer you will probably be assigned to Repair 5 (propulsion repair) for a general quarters station. Repair 5 usually has an engineering department officer or the chief petty officer in charge. The damage control party you must supervise is composed of an electrical officer (or senior Electrician's Mate) and a broad cross section of engineering ratings. Emphasis on assignment of personnel to Repair 5 is placed on fireroom and engineroom takeover qualifications rather than damage control qualifications. On larger ships, Repair 5 may be split. Each half of the party is assigned one-half of the engineering plant so that maximum use of manpower and equipment, and greater dispersal of personnel may be realized. Each section of the repair party is assigned sufficiently qualified engineering casualty control and damage control personnel.

Although your main function is for engineroom and fireroom takeover, your repair party must still be able to function as a damage control repair party if the need arises. Being the leader, you must be familiar with all the equipment used and the function of each. You must train your personnel in the use of the equipment and the functions of a repair party. Following is a list of functions which are common to all repair parties:

1. Each party must be capable of making repairs to electrical and sound-powered telephone circuits.

2. Each party must be capable of giving first aid and transporting injured personnel to battle dressing stations without seriously reducing the damage control capabilities of the repair party.

3. Each party must be capable of detecting, identifying, and measuring dose and dose-rate intensities from radiological involvement, and of surveying and decontaminating contaminated personnel and areas, except where specifically assigned to another department as in the case of nuclear weapons accident/incident.

4. Each party must be capable of sampling and/or identifying biological or chemical agents, and of decontaminating areas and personnel affected as a result of biological or chemical attack, except where this responsibility is assigned to the medical department.

5. Each party must be capable of controlling and extinguishing all types of fires.

6. Each party must be organized to evaluate and report correctly the extent of damage in its area. This will include maintaining:

- Deck plans showing locations of NBC contamination, battle dressing and personnel cleaning stations, and safe routes to them.

- A casualty board for visual display of structural damage.

- A graphic display board showing damage and action taken to correct disrupted or damaged systems. The use of standard control symbology and the accompanying preprinted message format are recommended to facilitate recording transmitted damage control information. Use the standard control symbology shown in figure 2-17 to read the message format in figure 2-18. In reading this message you should have come up with the following information: An 8-inch hole, 4 feet up from the deck at frame 38, starboard side of compartment 2-35-0-L.

Some of the specific functions for which Repair 5 is responsible in its own assigned area are listed below:

1. Maintenance of stability and buoyancy—members of the repair party must be:

a. Stationed so that they can reach all parts of their assigned area with a minimum opening of watertight closures.

b. Able to repair damage to structures, closures, or fittings that are designed to maintain watertight integrity, by shoring, plugging, welding, caulking the bulkheads and decks, resetting valves, and blanking or plugging lines through watertight subdivisions of the ship.

c. Be prepared to sound, drain, pump, counterflood, or shift liquids in tanks, voids, or other compartments; and be thoroughly familiar with the location and use of all equipment and methods of action.

d. Maintain two status boards for accurate evaluation of underwater damage: the Stability Status Board (Flooding Effects Diagram) to be used for visual display of all flooding, flooding boundaries, corrective measures taken, and effects on list and trim; the Liquid Load Status Board to show the current status of all fuel and water tanks and the soundings of each tank in feet and inches.

2. Maintenance of ship's propulsion—the personnel in the repair party must be able to:

a. Maintain, make repairs, or isolate damage to main propulsion machinery and boilers.

b. Operate, repair, isolate, and modify the segregation of vital systems.

c. Assist in the operation and repair of the steering control systems.

d. Assist in the maintenance and repair of communications systems.

e. Assist Repairs 1, 2, 3, and 4 and the crash and salvage team when required.

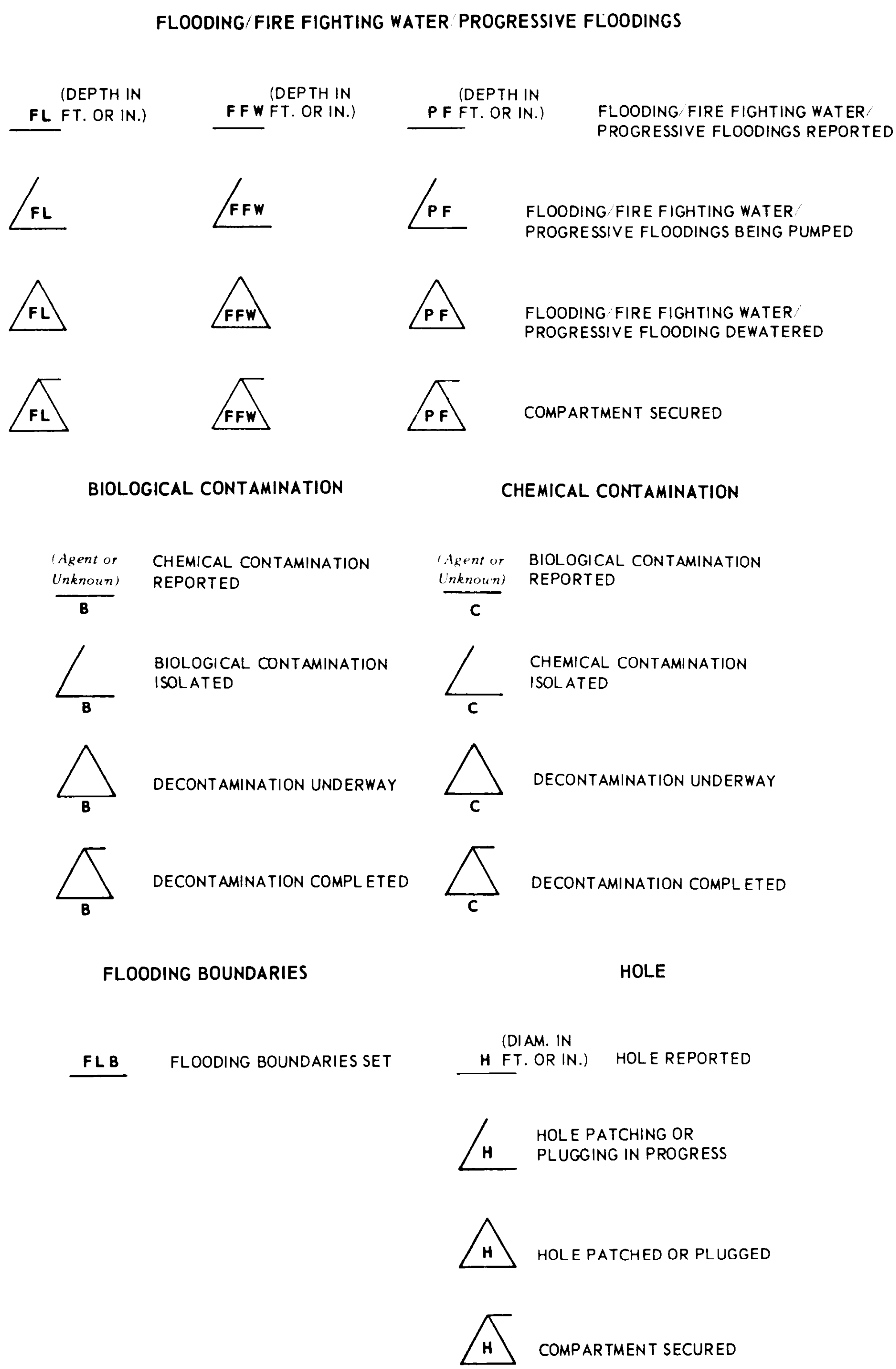


Figure 2-17.—Navy Standard Damage Control Symbology. 8.83(188)BC

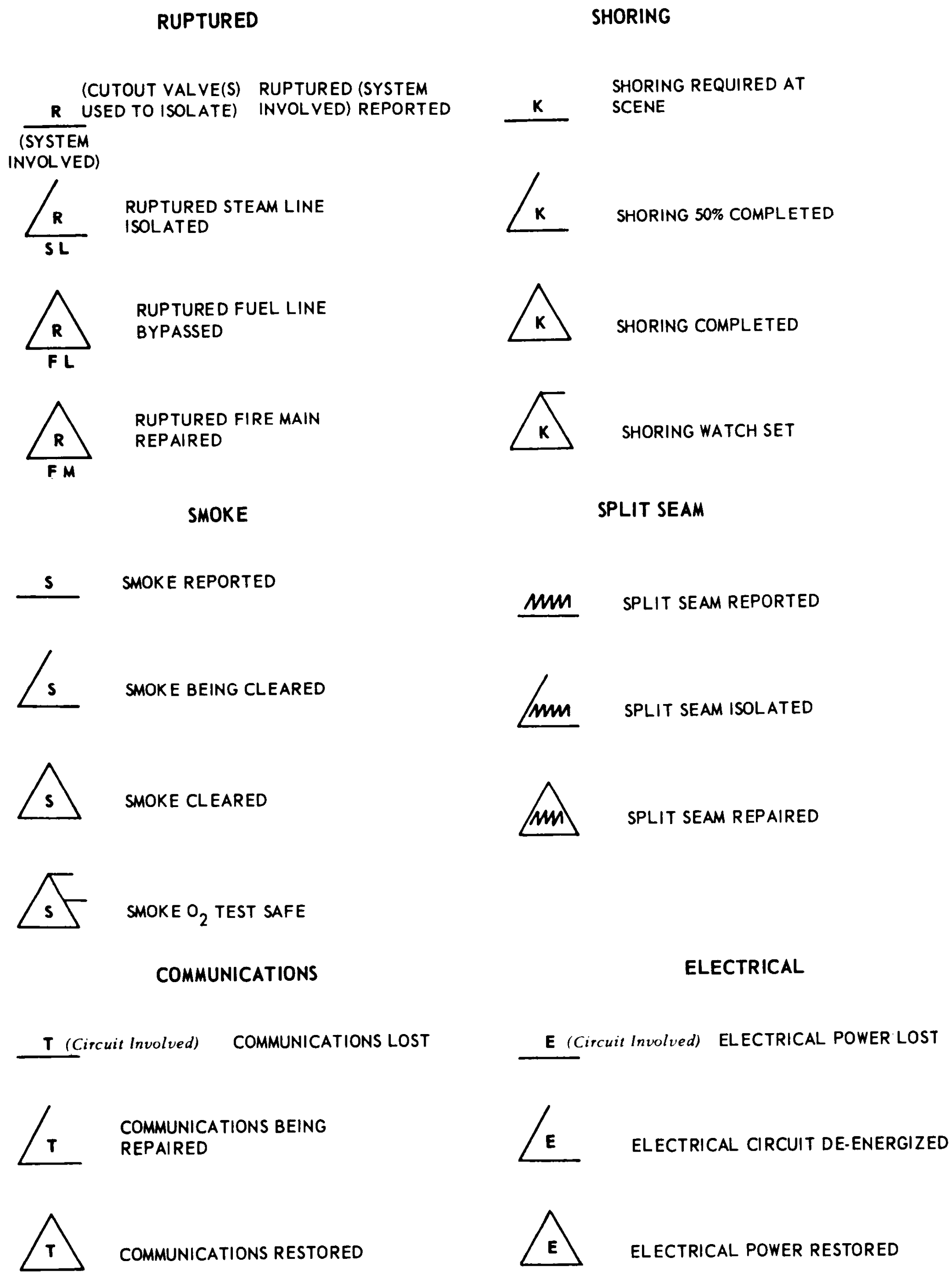


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Figure 2-17.—Navy Standard Damage Control Symbology—Continued.

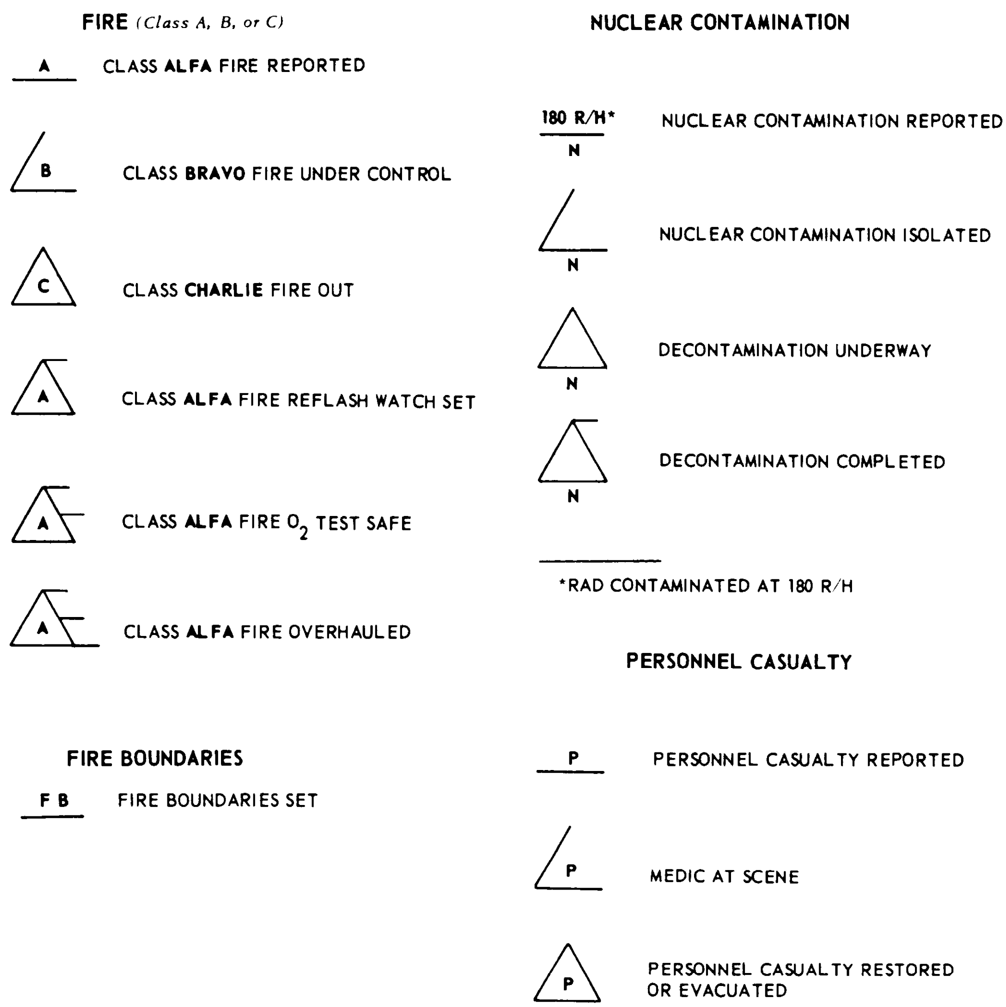

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Figure 2-17.—Navy Standard Damage Control Symbology—Continued.

Engineering Operational Sequencing System

To help make the job of supervision and training easier and more effective, and enhance the operational capability of shipboard engineering personnel, the Navy has developed a system known as the Engineering Operational Sequencing System (EOSS). Essentially, the EOSS is to the operator what the PMS is to the maintainer.

OPERATIONAL PROBLEMS.—The main propulsion plants in the ships of the modern day Navy are becoming more technically complex as each class of ship is built and joins the fleet. Increased complexity requires increased engineering skills for proper operation. Ships that lack the required experienced personnel have had material casualties which jeopardized their operational readiness. In addition, the rapid turnover of the engineering personnel who man and operate the ships further compounds the problem of developing and maintaining a high level of operator and operating efficiency.

The Navy has been increasingly aware of these problems and has undertaken studies to evaluate the methods and procedures presently used in operating complex engineering plants. The results

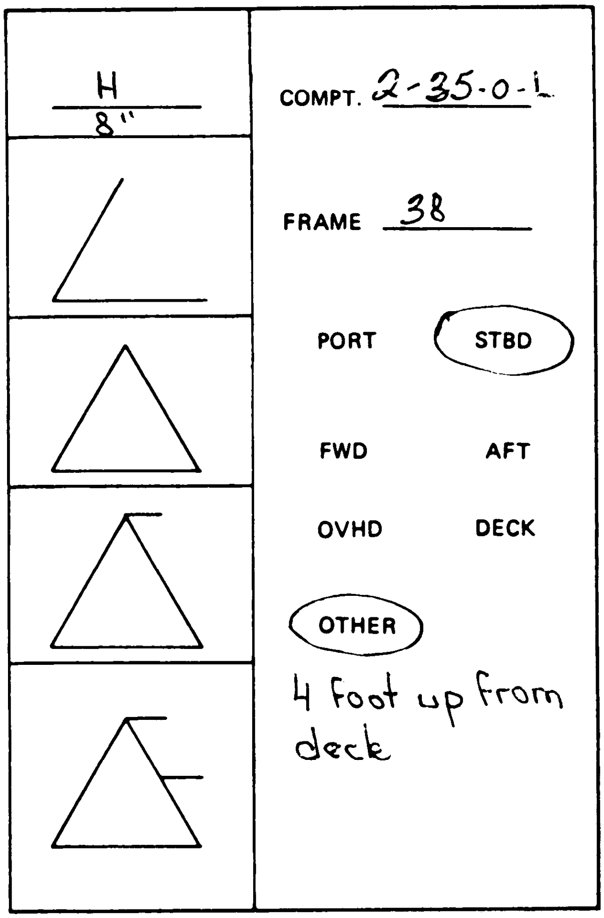

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Figure 2-18.—Preprinted message format.

of these studies have shown that in many instances sound operating techniques were not followed. Some of the circumstances found to be prevailing in engineering plants are described below:

- The information needed by the watchstander was usually scattered throughout publications which were generally not readily available.

- The bulk of the publications were not systems oriented. Reporting engineering personnel had to learn specific operating procedures from "old hands" presently assigned. Such practices could ultimately lead to misinformation or degradation of the transferred information. They were costly and resulted in non-standard operating procedures not only between adjoining spaces but also between watch sections within the same space.

- The posted operating instructions often do not apply to the installed equipment. They were conflicting or incorrect. No procedures were provided for aligning the various systems with other systems.

- The light-off and securing schedules were prepared by each ship and were not standardized between ships. The schedules were written for general, rather than specific, equipment or system values and did not include shifts between all the existing modes of operation.

Following these studies, NAVSEA developed the EOSS, designed to help eliminate operational problems. EOSS involves the participation of all personnel from the department head to the watchstander on watch. The EOSS consists of a set of systematic and detailed written procedures which utilize charts, instructions, and diagrams developed specifically for the operational and casualty control function of a specific ship's engineering plant and configuration.

EOSS is designed to 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 the equipment life. These objectives are accomplished by first defining the levels of control and operating within the engineering plant and then providing each supervisor and operator with the information needed—in words they could understand—at their watch station.

The EOSS is comprised of three basic parts:

- The User's Guide

- The Engineering Operational Procedures (EOP)

- The Engineering Operational Casualty Control (EOCC)

EOSS USER'S GUIDE.—The User's Guide is a booklet which explains the EOSS package and how it is used to the ship's best advantage. It contains document samples and explains how they are used. It provides recommendations for introducing the EOSS system and the methods for training the ship's personnel in utilizing the procedures set forth in this system.

EOSS documentation is developed using work-study techniques. All existing methods and procedures for plant operation and casualty control procedures are documented, including the actual ship procedures as well as those procedures contained in available reference sources.

Each action taken is subjected to a critical examination to evaluate the adequacy of the present procedures. At the completion of this analysis phase new procedural steps are developed into an operational sequencing system, and step-by-step time-sequenced procedures and configuration diagrams are prepared to show the plant layout in relation to operational components. The final step in the development phase of an EOSS is a validation on board ship check conducted to ensure technical accuracy and adequacy of the prepared sequencing system. All required corrections are made and then incorporated into the package before installation aboard ship.

The resulting sequencing system provides the best tailored operating and engineering operational casualty control procedures available pertaining to a particular ship's propulsion plant. Each level is provided with the information required to enable the engineering plant to respond to any demands placed upon it.

ENGINEERING OPERATIONAL PROCEDURES (EOP).—The operational portion of the EOSS contains all the information necessary for the proper operation of a ship's engineering plant. It also contains guides for scheduling, controlling, and directing plant evolutions through operational modes from receiving shore services, to various modes of inport auxiliary plant steaming, to underway steaming.

The EOP documentation is prepared for specifically defined operational stages. These are defined as Stages I, II, and III.

Stage I is considered as the total engineering plant level under the direct cognizance of the plant supervisor (EOOW). The officer coordinates the placing in operation and securing of all systems and components normally controlled by the various space supervisors. The EOOW also supervises those functions which affect conditions external to the engineering plant such as jacking, testing, and spinning main engines. The EOP documentation assists you, the plant supervisor, in ensuring optimum plant operating efficiency, properly sequencing of events in each operational evolution, and the training of newly assigned personnel. During a plant evolution, you will control and designate the operation of the following systems and components:

- Systems that interconnect one or more engineering plant machinery spaces and the electrical system.

- Major components such as boilers, main engines, and electrical generators.

- Systems and components required to support the engineering plant or other ship functions such as distilling plants, air compressors, steam system to catapults, and thrust blocks which are placed in operation or secured in response to demand upon their services.

To assist you the plant supervisor with these operations, the EOP section provides you with the following documents:

- Index pages listing each document in the Stage I station book by identification number and title.

- Plant procedure charts (figure 2-19) providing step-by-step procedures for each engineering plant evolution. (NOTE: At the time this publication was prepared for printing, EOSS diagrams illustrating specific equipment for which the Engineman is responsible were not available; the example used, in this section, however, illustrates the types of EOSS diagrams used regardless of equipment .)

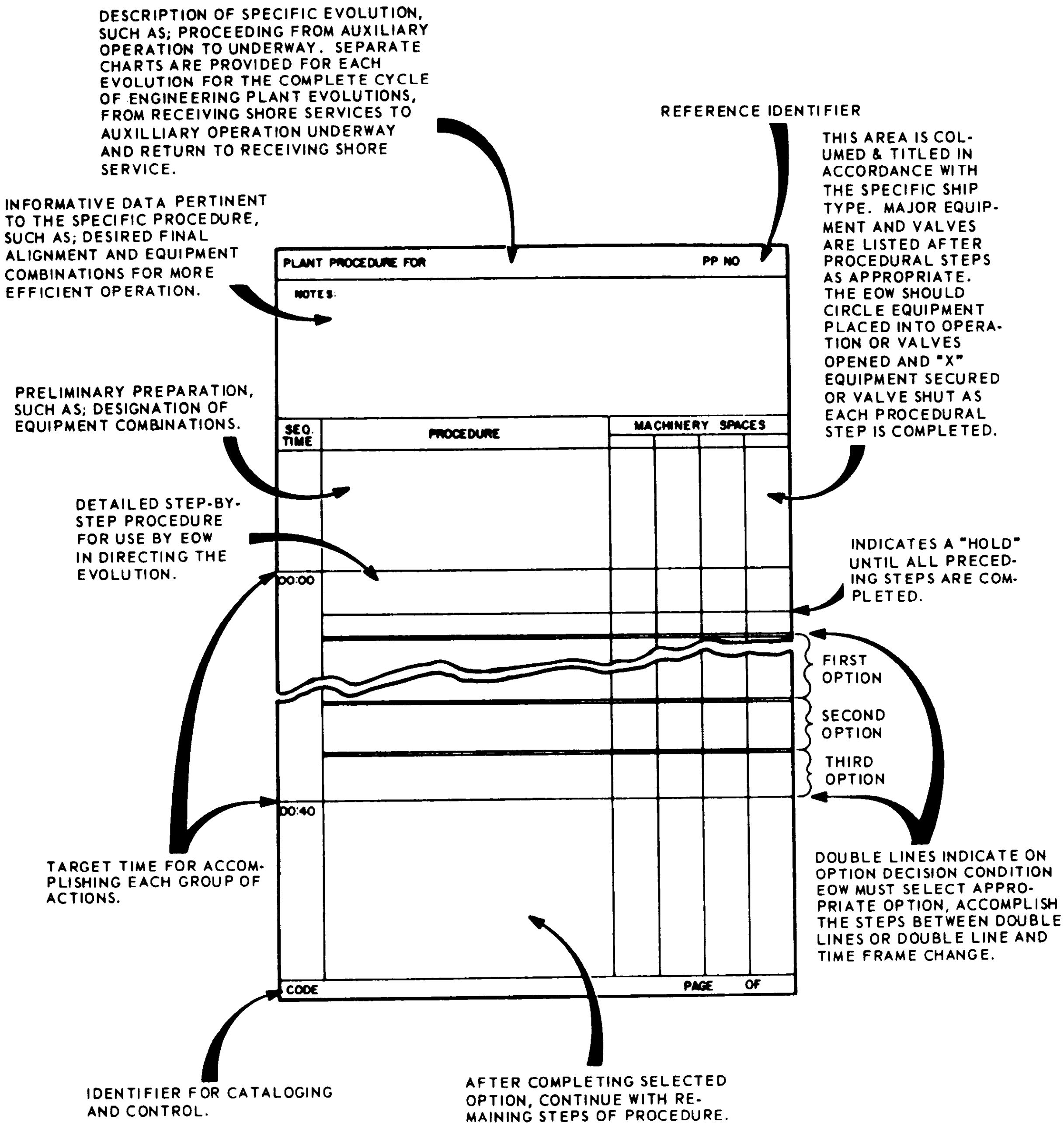

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Figure 2-19.—Sample plant procedure Chart.

- Plant status boards (figure 2-20) providing a systematic display of the major systems and cross-connect valves as well as a graphic presentation of the major equipment in each machinery space. These boards are used to maintain a current plot of systems alignment and equipment operating status.

- A diagram for plant steaming conditions versus optimum generator combinations

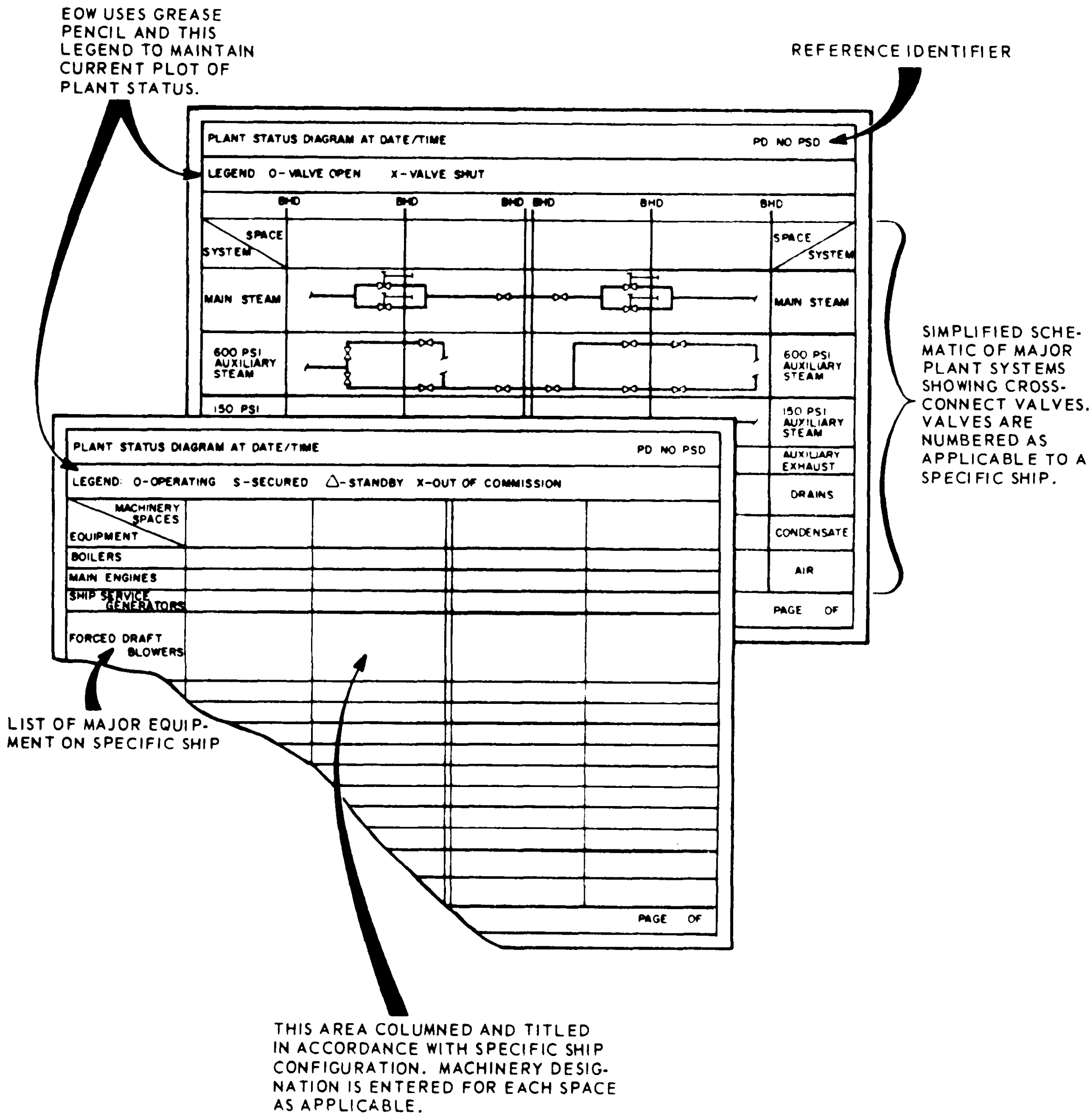

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Figure 2-20.—Sample Plant Status Diagram.

delineating the preferred electric power generator combinations for the various plant operating conditions. This diagram is also provided in the Stage II electrical documentation.

- System alignment diagrams (figure 2-21) delineating the preferred initial and final alignment for each engineering plant.

- A diagram for equipment versus speed requirement delineating the equipment normally required for various ship speeds.

- A diagram for shore services connection locations delineating the location of shore service connections for steam, electrical power, feedwater, potable water, and saltwater, and fuel oil.

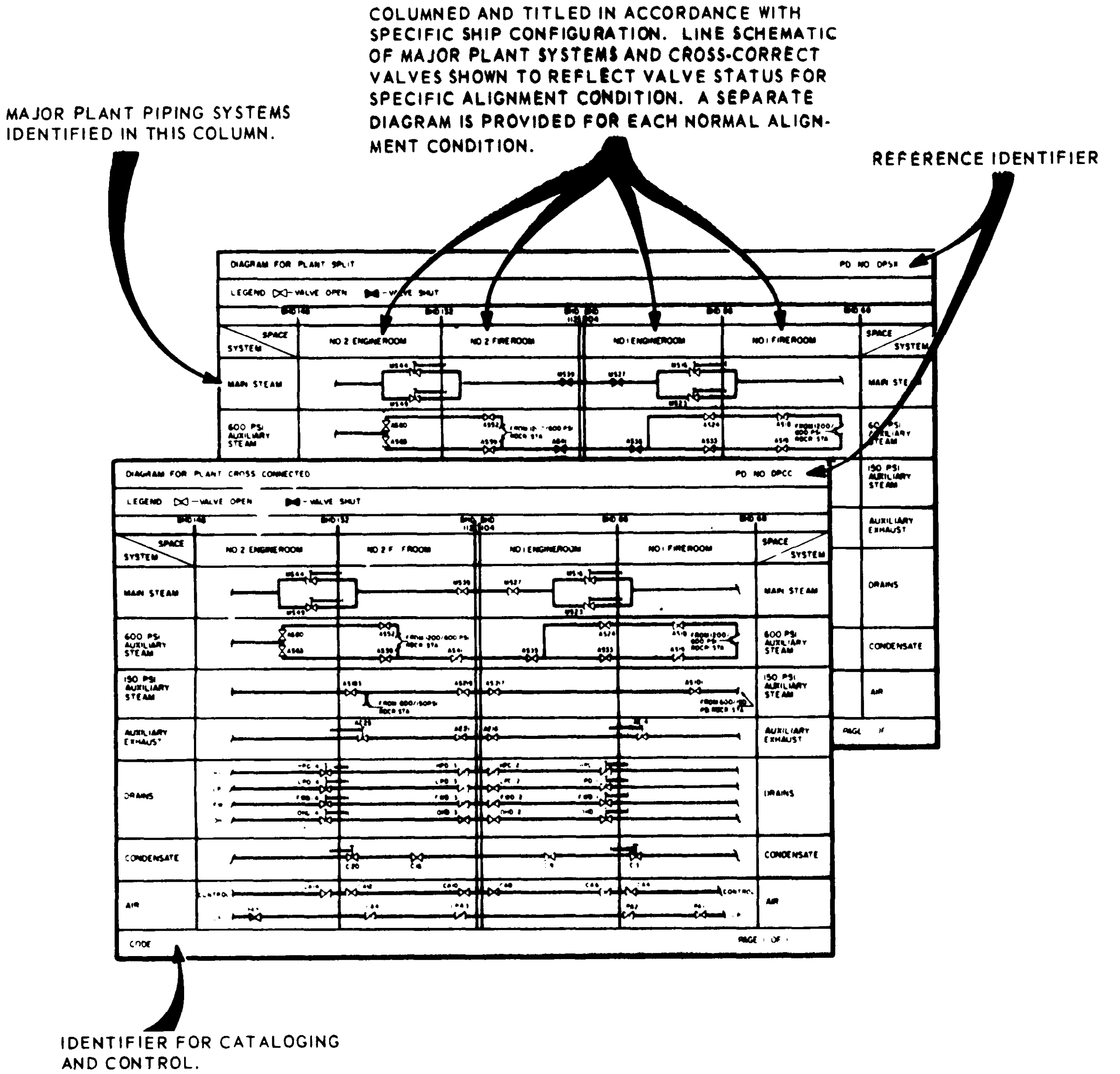

Figure 2-21.—Sample preferred alignment diagrams.

- Training diagrams (figure 2-22) delineating each major piping system to aid in plant familiarization and training of newly assigned personnel. These diagrams indicate the relative locations of lines, valves, and equipment.

Stage II is considered as the system component level supervised by the space supervisor in each engineroom and fireroom, and the electrical plant supervisor (electrical load dispatcher). In Stage II, the space supervisor accomplishes the tasks delegated by the plant supervisor. The EOP documentation assists the space supervisor in properly sequencing the events, controlling the operation of equipment within the machinery space or electric-power complex in maintaining

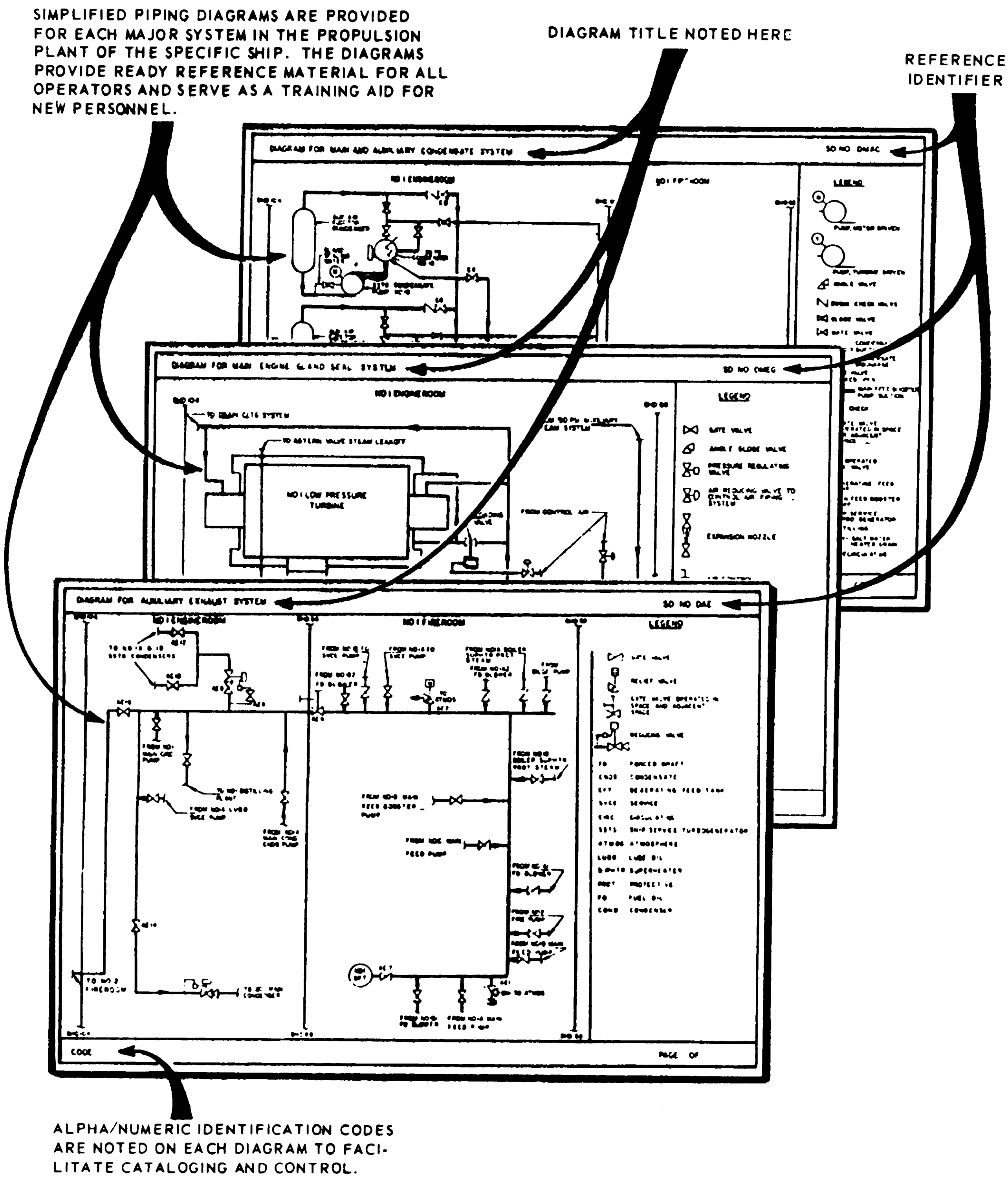

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Figure 2-22.—Sample Training Diagrams.

an up-to-date status of the operational condition of the assumed equipment assigned and in training newly assigned personnel. To assist the space supervisor in this effort, the EOP section provides the following Stage II documents:

- Index pages listing each document by identification number and title for each specified operating group such as engineroom, fireroom, electrical, etc.

- Space procedure charts (similar to the plant procedure chart) providing the step-by-step procedure to be accomplished within a space to satisfy and support the requirements of the plant procedure charts.

- Space status board providing a schematic of major systems and a tabular listing of the major equipment within the individual machinery spaces for maintaining a plot of systems alignments and equipment operating status. This board is similar in configuration to that provided for the Stage I documentation (figure 2-20).

- Diagram for Electrical Plant Status (DLS) delineating generators, switchboards, and shore-power connections within the electrical distribution systems. The DLS is provided in both the electrical operating group and in the Stage I (EOOW) documentation for maintaining a plot of the system alignment.

- Diagram for plant steaming conditions versus optimum generator combinations provided in the electrical operating group documentation delineating the preferred electric power generator combination. This diagram is the same as that provided in the Stage I documentation.

- Training diagrams of each major piping system developed for Stage I, plus diagrams of such systems as fuel-oil service, and main engine lube oil that are normally located within the machinery spaces.

Stage III is considered as the system component level attended by the component operators. The component operators place equipment in and out of operation, align systems, and monitor and control their operation by manipulating the required valves, switches, and controllers. Stage III documents include:

- Index pages listing each document by identification number and title for each specified system such as fuel-oil service system, lube oil service system, etc.

- Component procedure cards providing step-by-step procedures for systems alignment or component operation.

- Component procedure cards as required to support each operation or alignment.

- Alignment diagrams (figure 2-23) amplifying the written procedure to assist the component operator in proper systems alignment. Alignment diagrams are provided whenever two or more alignment conditions exist for a given system or component.

The operational use of EOP documentation is of primary importance at all levels in controlling, supervising, and operating the evolutional functions of the engineering plant.

ENGINEERING OPERATIONAL CASUALTY CONTROL (EOCC).—The casualty control portion of EOSS contains information relative to the recognition of casualty symptoms and their probable causes and effects. In addition, it contains information on preventive action to be taken to preclude a casualty and on procedures for controlling single and multiple source casualties.

Casualty prevention must be the concern of everyone on board. Proper training of all personnel must provide for adequate knowledge and experience in effective casualty prevention. The EOCC manual contains efficient, technically correct casualty control and prevention procedures which relate to all phases of an engineering plant. The EOCC documents elaborate on possible casualties caused by error, material failure, and battle. The EOCC manual describes tried and proven methods for the control of a casualty and prevention of further damage to the component, the system, or the engineering plant concerned.

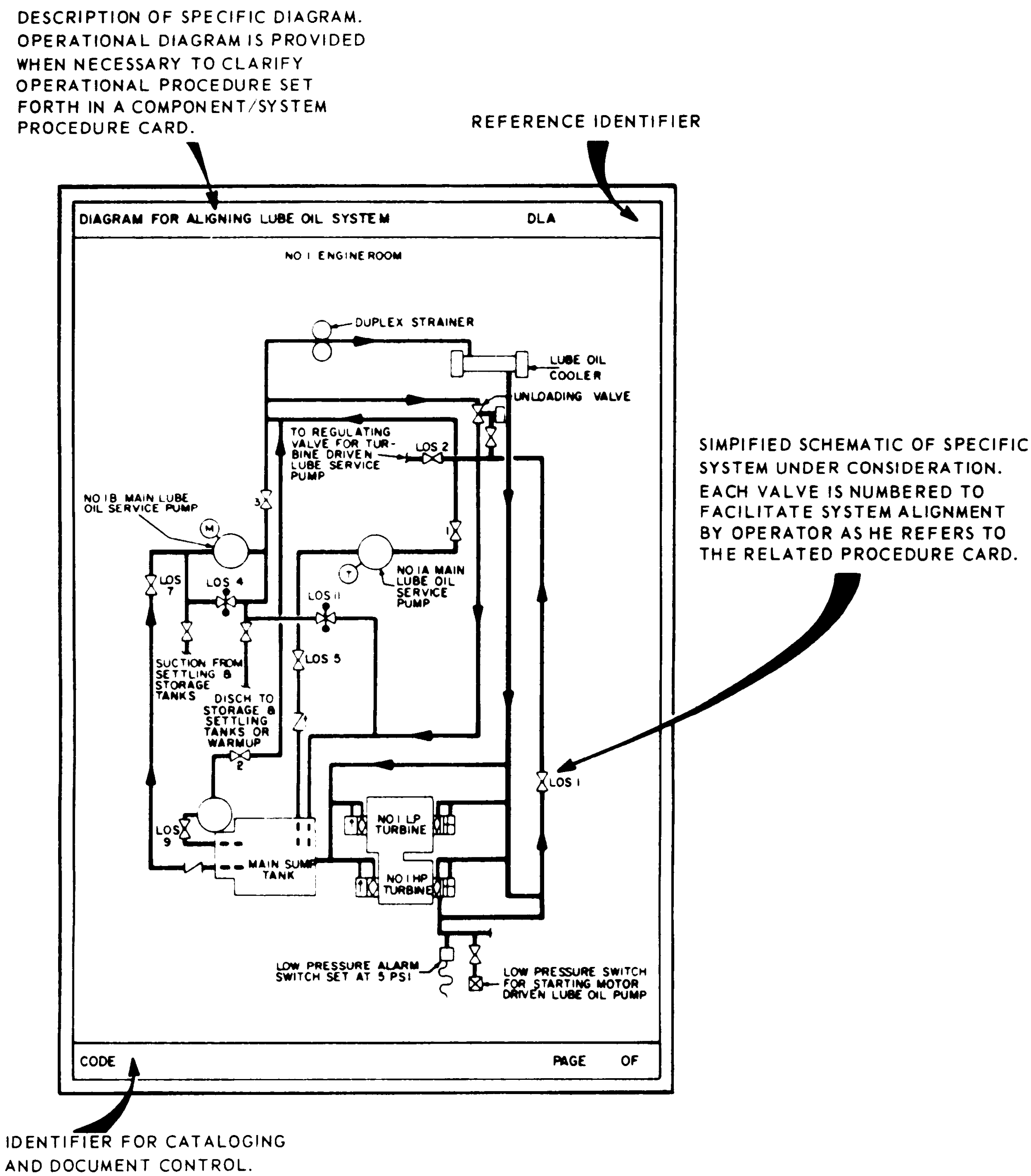

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Figure 2-23.—Sample Component/System Alignment Diagram.

The EOCC manuals are available to the personnel in their own machinery space so that they can be used as a means of self-indoctrination for newly assigned personnel and as an instrument with which to improve casualty control procedure techniques for all watchstanders. The manual contains the documentation required to effectively assist engineering personnel in developing and maintaining maximum proficiency in controlling casualties to the ship's propulsion plant.

Proficiency in EOCC procedures is maintained through a well-administered training program. Primary training concentrates on controlling single-source casualties—those which may be attributed to the failure or malfunction of a single component or the failure of piping at a specific point in a system. Advanced training concentrates on controlling multiple casualties or on conducting a battle problem. An effective and well-administered EOOW training program must contain, as a minimum, the following elements:

- Recognition of the symptoms.
- Probable causes.
- Probable effects.
- Preventive actions that may be taken to reduce, eliminate, or control casualties.

An EOSS package is not intended to be forgotten once it is developed and installed aboard a ship. It offers many advantages to the ship's operational readiness capabilities, providing detailed step-by-step sequencing of events for all phases of the engineering-plant operation. Its procedures are tailored to each specific ship and are prepared for each level of management and operation. Because it is work-studied and system-oriented, the EOSS provides the basic information for the optimum utilization of equipment and systems by specifying correct procedures tailored for a specific plant configuration.

The EOSS is not intended to eliminate the need for skilled plant operators. No program or system can achieve such a goal. The EOSS is a tool for better utilization of manpower and skills available. Although the EOSS is an excellent tool for shipboard training of personnel, it is primarily a working system for scheduling, controlling, and directing plant operations and casualty-control procedures.

OPERATING INSTRUCTIONS AND SAFETY PRECAUTIONS

A master list of all the engineering department operating instructions and safety precautions is kept in the log room. When a ship is commissioned, the building yard normally provides a master copy of this list, 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.

For ships in commission and in service, plastic laminated operating instructions and safety precautions are available; they are listed in the *Navy Stock List of Forms and Publications,* NAVSUP Publication 2002.

INSPECTIONS AND TRIALS

A naval ship must be inspected from time to time to ensure that its operation, administration, and equipment reflect a high standard of readiness for war. The frequency with which the various types of inspections are held are determined by the 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 and reports, you will always be ready for an inspection.

Since your ship may be required to furnish an inspecting party to make an inspection on another ship, 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. 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 whether or not (1) the department is being administered in an intelligent, sound, and efficient manner; and (2) the organizational and administrative methods and procedures are directed toward the objective of every naval ship-namely, being prepared to carry out its intended mission.

Inspecting Party

It is a routine procedure for one ship to conduct an inspection of a similar division on another ship. 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 must conduct the inspection.

The chief inspector, usually the commanding officer of the ship, will organize the assisting board. The organization of the assisting board, in general conformance with the departmental organization of the ship, is divided into appropriate groups, each headed by an inspector with as many 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) is organized and supervised by the engineer officer. The manner in which an individual inspection is carried out depends to a great extent upon the knowledge and ability of the members of the group (or party).

General Inspection of the Ship as a Whole

One of the two categories of administrative inspection is 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 education facilities for individuals.
8. Comfort and conveniences of living spaces, including adequacy of light, heat, ventilation, and freshwater.
9. Economy of resources.

Engineering Department Inspection

The engineering department administrative inspection is primarily the inspection of the engineering department paper work, which includes publications, bills, files, books, records, and logs. Additionally, this inspection includes other items with which the chief and first class must be concerned. Some of these items are the cleanliness and preservation of machinery and engineering spaces; the training of personnel; the assignment of personnel to watches and duties; the proper posting of operating instructions and safety precautions; the adequacy of warning signs and guards; the marking and labeling 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, to assist them in ensuring that no important item is overlooked. However, inspecting personnel should not accept these lists as being all-inclusive, since usually during an inspection, additional items develop that must be considered or observed.

As a petty officer, you should be familiar with the various checkoff lists used for inspections.

These 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 about what type of inspection you may expect for your type of ship.

Following is an abbreviated sample of an engineering department checkoff list. You should get a better understanding of the scope and purpose of administrative inspections by reviewing this 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 personnel in training to replace anticipated losses?

(2) NAVEDTRA training courses:

(a) Number of personnel enrolled.

(b) Percentage of personnel in department enrolled.

(c) Number of personnel 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 personnel 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 personnel examined and qualified for important watches?

d. Does it appear that personnel on watch have been properly instructed? (Question personnel at random.)

5. OPERATING INSTRUCTIONS, SAFETY PRECAUTIONS, PMS, AND CHECKOFF LISTS:

a. Inspect completeness of the following:

(1) Operating instructions posted near machinery.

(2) Posting of necessary safety precautions.

b. Are PMS schedules properly posted and maintained in the working spaces?

c. Is the Master PMS Schedule posted and up to date?

d. Are responsible personnel familiar with current instructions regarding routine testing and inspections?

e. 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 replacement 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 handtools?

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 a repair part for a certain piece of machinery is obtained.)

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. *NAVSEA 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 is conducted to ensure that the ship is ready and able to perform the operations which might be required of it in time of war.

This inspection consists of the conduct of a battle problem and of other operational exercises. A great deal of emphasis is placed on AA and surface gunnery, damage control, engineering casualty control, and other appropriate exercises. Various drills are held and observed, and the ship is 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 are similar to those of the administrative inspection party. However, more personnel are usually required for the operational readiness observing party. These additional personnel are very often chiefs and first class petty officers.

The observing party members are briefed in advance of the scheduled exercises and about the drills that are to be conducted. They must have sufficient training and experience so that they can properly evaluate the exercises and drills that are to be held. Each observer is usually assigned to a specific station, and should be well qualified in the procedure of conducting drills and exercises for that station. That each observer be familiar with the type of ship to be inspected is also highly desirable.

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. The knowledge of the viewpoint and duties of an observer should help you prepare yourself and your personnel for a battle problem and other appropriate exercises.

PREPARATION OF A BATTLE PROBLEM.—The degree of perfection achieved in any battle problem is reflected in the skills and applications 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.

Battle problems are the most profitable and significant of all peacetime training experience, since they demonstrate a department's readiness for combat. The degree of realism of this test determines their value: the more nearly it approximates actual battle conditions, the more valuable it is.

Another element in the conduct of a battle problem which significantly increases the value of these tests to the ship's company is the element of surprise.

CONDUCT OF A BATTLE PROBLEM.—Before a battle problem is to be conducted, the ship is furnished specific information such as that listed below:

1. Authority for conducting the inspection.
2. Time of boarding of the inspecting party.
3. Time the ship is to get underway.
4. Time for setting the first material readiness condition.
5. Time for conducting the inspection to zero problem time conditions.
6. Zero problem time.
7. End of problem time.
8. Time of critique.

Observers must be proficient in the proper methods of introduction of information. In general, when practical, the information delivered to ship's personnel should be verbal, and should contain only that information which would help the ship's personnel develop adequate procedures for the search and investigation of the imposed casualty. In the event the ship's personnel fail to locate the casualty, the observer 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 case 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 the experience of personnel. The supply of lubricating oil to the main engines or the supply of feedwater to the boilers MUST NOT be stopped to simulate casualties.

An emergency procedure should be set up, by the observing party and ship's company, to ensure proper action in case actual casualties—as distinguished from simulated or problem casualties—should occur.

Although the general announcing system (the 1MC circuit) may be used by the ship, observers, normally, have priority in its use. The problem time announcer uses the general announcing system to announce the start of the battle problem, the problem time at regular intervals, the conclusion of the problem, and the restoration of casualties. The general announcing system is kept available at all times for use in case of actual emergency. All other announcing system circuits and 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 the proper handling of information or casualties.

An inspection should be made to see that the engineering plant is properly split in accordance with current directives. Fire hazards such as paint, rags, or oil, and missile hazards such as loose gear, loose floor plates, tool boxes, and repair parts boxes should be noted. The condition of firefighting, damage control, and remote control gear should be carefully inspected.

ANALYSIS OF THE BATTLE PROBLEM.—The maximum benefit obtained from conducting a battle problem lies in pinpointing existing weaknesses and deficiencies, and in the resulting recommendations for improvement in organization and training. Every effort should be made by the observers to emphasize strong points as well as deficiencies. Knowledge of existing strong points is helpful to boost the morale of the ship's personnel.

Analysis of the battle problem affords the observers an opportunity to present to the ship their opinion of its performance, and for the ship to comment on the observers' remarks as well as to consider suggested improvements.

Analysis is conducted in two steps: the critique and the observers' reports.

A critique of the battle problem is held on board the observed ship before the observing party leaves, in order that the problems and the actions taken may be reviewed when they 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 complete their analysis of the battle problem as reported in their observers' reports.

The observers' reports are prepared in the form prescribed by the type commander, and include any additional instructions given by the chief observer. The reports of the observers are collected by the senior observer for each department and are submitted to the chief observer. All observers' reports are reviewed by the senior observers before the critique is held.

The observers' reports provide the inspected ship with detailed observations of the battle problem which, because of time limitations, may not have been 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 review the comments and set up a training schedule to cover the weak points.

Following is a example of an engineering observer's report.

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. Were 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 transmission 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 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. 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 it was designed. In addition, the material inspection determines whether or not proper procedures are being carried out in the care and operation of machinery and equipment. Administrative procedures and material records which are inspected include maintenance records and routine tests, and inspections.

The requirements prescribed for material readiness are as follows:

1. Established routines for the conduct of inspections and tests, schedule for preventive maintenance, and a system which will ensure timely and effective repairs.

2. Adequate material maintenance records, kept in accordance with current directives that give the history and detailed description of the condition of the machinery and the 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 material inspection is similar to that of the inspection made by the Board of Inspection and Survey. (These inspections are discussed later in this chapter.) These inspections should be thorough and searching, and cover, in detail, maintenance and repair rather than general appearance. The distinction between administrative inspections and material inspections should be readily recognized, and there should be as little duplication as possible. Examination of the material maintenance records and reports should be made to determine 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.

The composition of the inspecting party for the material inspection is similar to that of the administrative. inspection party.

Preparation for the Material Inspection

At an appropriate time prior to the date of the inspection, the chief inspector will furnish the ship with advance instructions. These instructions will include:

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 case of 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. These are checkoff lists which are used for the material inspection.

4. Any additional instructions considered necessary by the type commander or other higher authority.

Each department must prepare work lists showing the items of work to be accomplished and the recommended means for accomplishment (shipyard, tender or repair ship, or ship's force during an overhaul or upkeep period.) The items are arranged in the recommended order of importance and numbered. A list of the outstanding alterations is also made up for the inspection. Work lists usually consist of 5 by 8 cards, with one repair or alteration item on each card. The work list should include all maintenance and repair items, because if material deficiencies are found during the inspection they will be checked against the work list. If the item does not appear on the work list, a discrepancy in maintaining the required records will be noted by the inspector.

CONDITION SHEETS.—Condition sheets are made up in accordance with the needs of the different material groups. The engineering department is primarily concerned with the machinery, the electrical, the damage control, and the hull condition sheets. Condition sheets contain checkoff sheets and material data sheets, and consist of a large number of pages. Items for data and checkoff 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 do this, detailed data is obtained from the maintenance records and reports.

An entry for any known fault or abnormal condition of the 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. If corrective work is required in connection with a unit or space, a reference is made to the work list item. Data and information requested in the condition sheets should be furnished whenever possible. The preliminary copy, if properly filled out, represents the best estimate of 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 fill in the various checkoff sections of the condition sheets. These sheets are then used to prepare the final inspection report on the condition of the ship.

For more detailed information concerning a 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, in order to obtain the inspector's opinion concerning known or probable defects. The information given in *Naval Ship's Technical Manual*, chapter 090, is used as a guide in opening particular machinery units. More detailed information on opening machinery for material inspections is 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 portable 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 as to be readily available for inspection. Records must 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 should check all records or reports that concern the material or the maintenance procedures of that space.

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 and a checkoff list in making the inspection. Appropriate remarks, comments, and recommendations are entered on the condition sheets for any particular unit of machinery or equipment.

The inspectors should conduct the inspection together with the ship's personnel. No attempt must be made to follow a predetermined inspection schedule, but different units should be inspected as they are made available by the 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 indicated below:

1. All opened machinery and equipment is carefully inspected, especially where the need of repair work is indicated on the work list.
2. Investigations are 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 conducted in accordance with the furnished list.
4. Electrical equipment is not endangered by saltwater from hatches, doors, or ventilation outlets. Possible leaks in piping flanges are checked.
5. Currently required firefighting and damage control equipment in the engineering space is installed and properly maintained in accordance with current directives.
6. Supports and running gear of heavy suspended material are inspected.
7. Hold-down bolts, plates, and other members of machinery foundations are inspected. Hammers may be used for sounding, and file scrapers may be used for removing paint in order to disclose any condition of metal corrosion.
8. Condition sheets are 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. Routine tests of mechanical and electrical safety devices are observed to ensure that they are being conducted according to current directives.
10. Maintenance records and reports are carefully inspected to see that they are maintained in accordance with prescribed procedures. A check is made to ensure that all known repair requirements are listed.

Analysis and Reports

A critique is 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 is attended by the ship's commanding and executive officers, the heads of departments, the chief inspector, and inspectors of each inspection group, and such other personnel as may be designated from the inspected ship.

The inspectors, after receiving data from the assistant inspectors, submit reports of their inspections to the chief inspector. These reports provide 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 reports include evaluations and any recommendations for the items inspected or observed. These reports are used by the ship as checkoff lists for corrective action and material improvement.

The chief inspector, after receiving the reports from the inspectors, makes up a report on evaluating and grading the inspection. The chief inspector discusses, with appropriate comment, the following items.

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 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 the president 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 will consider 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 made by the 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 procedures, condition sheets, and reports are used as guidelines 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 routine shipboard material inspection. It must be remembered that the Board of Inspection and Survey conducts other types of inspections.

Inspections of ships are conducted by the Board of Inspection and Survey, when directed by CNO, to determine their material condition. Their inspection usually takes place 4 to 6 months prior to regular overhaul. Whenever practicable, such inspections are held sufficiently in advance of a regular overhaul of the ship so as to include in the overhaul all the work recommended by the Board following the inspection. Upon the completion of its inspection, the Board reports 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 there to 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, either during the trials or as a result of examination at the completion of trials, are reported by the Board, together with its recommendations as to the responsibility for correction of defects and deficiencies. The Board also recommends any changes in design which it believes should be made on the ship itself or other ships of its type. These recommendations are made to the Secretary of the Navy.

Unless war circumstances prevent it, an acceptance trial takes place at sea over an established trial course. The tests include full power runs ahead and astern, quick reverse, boiler overload, steering, and anchor engine tests. During the trial, usually the builder's personnel operate the ship and its machinery. Ship's personnel who are on board to observe the trial carefully inspect the operation and material condition of machinery and equipment. They note all defects or deficiencies and bring them to the attention of the division or engineer officer, so that each item 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 after a thorough inspection, renders 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.

When the Board believes that the ship is unfit for further naval service, the Board makes 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. A list comprising most of them is given here:

1. Builder's trial.
2. Acceptance trials.
3. Final contract trials.
4. Post repair trials.
5. Laying up or pre-overhaul trial.
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 3, 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 *Naval Ships' Technical Manual,* chapter 094.

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 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 are largely determined by the character of the work that has been performed. The trial should be conducted in such manner as the commanding officer and commander of the shipyard may deem necessary. In cases where repairs have been slight and the commanding officer is satisfied that they are satisfactorily performed and can be tested without a full power trial, such trial may be dispensed with.

Any unsatisfactory, conditions found to be beyond the capacity of the ship's force should be corrected by the naval shipyard. When 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 trial.

A certain number of naval shipyard personnel—technicians, inspectors, and repairmen—accompany the ship on a post repair trial. They check the operation of machinery that has been overhauled by the yard. If a unit of machinery does not operate properly, the yard technicians carefully inspect it 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 competitive trials.

Trials are also held from time to time to determine machinery efficiency under service conditions, the extent, if any, 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 must report to the commanding officer the condition of the machinery, stating whether or not it is in proper condition and fit to proceed with the trial.

GENERAL RULES FOR TRIALS.—During all full power trials, and during other machinery trials, the following general rules should be observed:

1. Prior to commencing a power trial, the machinery should be thoroughly warmed up; this

can be accomplished by operating at a high fractional power.

2. The speed of the engines should be gradually increased to the speed specified for the trial.

3. The machinery should be operated economically, and designed pressures, temperatures, and number of revolutions must not be exceeded.

4. 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.

5. A full power trial should continue beyond the length originally specified, and all observations should be continued until the trial is finished.

6. The trial should be continuous and without interruption. If a trial at constant rpm must be discontinued for any reason, that trial should be considered unsatisfactory and a new start made.

7. No major changes of the plant set-up or arrangement should be made during economy trials.

UNDERWAY REPORT DATA.—Reports of trials 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 drydocked; the consumption of fuel 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 was determined should also be described.

Reports should also include tabulations of gage and thermometer readings of the machinery in use, and the revolutions or strokes of pertinent auxiliaries. The auxiliaries in use during the trial should be stated. Each report should state whether the machinery is in a satisfactory condition. If the machinery's condition is found to be unsatisfactory, all defects and deficiencies should be fully described and recommendations made for correcting them.

TRIAL REQUIREMENTS.—Trial requirements for each ship cover the rpm for full power at various displacements and injection temperatures. They are furnished to commanders and units concerned, by the Chief of Naval Operations (Operations Readiness Division).

As far as reports are concerned, full power trials are of 4 hours duration. The usual procedure is to operate the ship at full power for a sufficient length of time until all readings are constant, and then start 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.

Once scheduled, trials should be run unless prevented by such circumstances as:

1. Weather conditions which might cause damage to the ship.
2. Material troubles which force the ship to discontinue the trial.
3. Any situation where 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.

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 are appointed from another ship whenever practicable. When a ship is scheduled to conduct a trial while proceeding independently between ports, or under the other conditions where it is considered impractical to provide observers from another ship, the ship under trial may be directed to appoint the observers.

The number of personnel assigned to an observing party vary according to size and type of ship. The duties of the observing party are usually as follows:

1. The chief observers organize, instruct, and station the observing party. They check the ship's draft, either at the beginning of the trial or before leaving port; supervise the performance of the engineroom observers; check the taking of counter readings; render all decisions in accordance with current directives; and check and sign the trial reports.

2. The assistant chief observers assist the chief observers as directed; supervise the performance of the observers; check the taking of fuel oil soundings and meter readings; and make out the trial reports.

3. Assistant observers take fuel soundings, meter readings, counter readings, the ship's draft, and collect all other data that may be required for the trial reports.

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.

3. 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% of the full load capacity.

4. The chief observer should determine draft and trim before and after the trial, verify the amount of fuel on board and correct this amount of the time of beginning the trial. The draft observer should also determine the rpm required for the full power trial, at the displacement and injection temperature existing at the start of the trial.

5. 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.

6. The chief observer should instruct members of the observing party to detect any violation of trial instructions, of instructions in the *Naval Ships' Technical Manual,* or of good engineering practice, and then verify any such report and provide the commanding officer or a detailed account of each 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 are 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, normally 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's report of the trial should state 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. Illustrations of these forms are not given in this training manual, but you can obtain copies from your log room, and in this way get an idea of the data and readings that are 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 important to make careful inspections and tests of equipment and items of machinery that may cause difficulties during full power operation, since it is possible that unknown defects or conditions may go undetected during operation at fractional powers—the normal operating condition of the ship most of the time.

Before a trial run is made, the main engines should be inspected to make sure that the power output of the individual cylinders is equal; this ensures a balanced, smooth-operating engine, at maximum speed and power. Equal load distribution between the individual cylinders depends on the following factors being as nearly equal as possible for all cylinders.

1. Compression pressures.
2. Fuel injection timing.
3. Quantity and quality of fuel injected.
4. Firing pressures.
5. Inlet valve timing and lift.
6. Exhaust valve timing and lift.
7. Exhaust gas temperatures.

A common practice among many commanding officers, when making full power trials, is first to bring the ship up to a speed of one or more knots below the trial run speed of the ship and then turn the control of the speed (except in cases of emergency nature) over to the engineer officer. The control engineroom, under the supervision of the engineer officer, brings the speed up slowly, depending upon the conditions of the plant, until the specified speed has been reached.

CHAPTER 3

ENGINE MAINTENANCE

Keeping an internal combustion engine (diesel or gasoline) in good operating condition demands a well-planned procedure of periodic inspection, adjustments, maintenance, and repair. If inspections are made regularly, many malfunctions can be detected and corrected before a serious casualty results. A planned maintenance program will help to prevent major casualties and the occurrence of many operating troubles.

The Maintenance and Material Management (3-M) System provides a logical and efficient approach to many maintenance problems. It produces a large reservoir of information about equipment disorder and indicates what corrective steps must be taken to prevent them.

Another aspect that must be considered in connection with maintenance problems is the safety requirement aboard ship. On some ships, the 3-M System includes safety requirement cards. A safety requirement card provides guidelines and periodicity for the inspection of selected areas not covered in the regular maintenance schedule.

Complete information about the 3-M System is contained in the *Maintenance and Material Management (3-M) Manual,* OPNAVINST 4790.4.

There may be times when service requirements will interfere with a planned maintenance program. In such event, routine maintenance must be performed as soon as possible after the specified interval of time has elapsed. All necessary corrective measures should be accomplished as soon as possible. Repair jobs should not be allowed to accumulate, otherwise hurried and inadequate work will result.

Since the Navy uses many models of internal combustion engines, it is impossible to specify a detailed overhaul procedure that would be adaptable to all models. However, there are several general rules which apply to all engines. They are:

1. Detailed repair procedures are listed in manufacturers' instruction manuals and in maintenance pamphlets. Study the appropriate manuals and pamphlets before attempting any repair work. Pay particular attention to tolerance limits, and adjustments.

2. Observe the highest degree of cleanliness in handling engine parts during overhaul.

3. Before starting repair work, be sure that all required tools and replacements for known defective parts are available.

4. Keep detailed records of repairs. Such records should include the measurements of parts, hours in use, and the names of the new parts installed. Analyses of such records will indicate the hours of operation that may be expected from the various engine parts. This knowledge is helpful as an aid in determining when a part should be renewed in order to avoid a failure.

Since maintenance cards, the manufacturers' maintenance manuals, and the various types of instructions discuss repair procedures in detail, this chapter will be limited to general information on engine inspections, adjustments, and maintenance, as well as some of the troubles encountered during overhaul, the causes of such troubles, and the methods of repair to be used.

INSPECTIONS

Inspections and maintenance are vital in order to maintain engines (diesel and gasoline) in proper operating condition and to minimize the occurrence of casualties caused by material failure.

A comparatively minor engine malfunction, if not recognized and remedied in its early stages, might well develop into a major casualty. You and your work center personnel must be able to recognize the symptoms of any developing malfunction by using your senses of sight, hearing, smell, or even touch or feel (heat/vibration).

Your personnel must be trained to pay particular and continuous attention to the following indicators of oncoming malfunctions:

1. Unusual noises
2. Vibrations
3. Abnormal temperatures
4. Abnormal pressures
5. Abnormal operating speeds

All operating personnel should thoroughly familiarize themselves with the specific temperatures, pressures, and operating speeds of equipment that are required for normal operation, so that any departure from the normal will become more readily apparent.

If a gage, or other instrument for recording operating conditions of machinery, gives an abnormal reading, the cause of the malfunction must be fully investigated. Normally the installation of a spare instrument, or a calibration test, will quickly indicate whether the abnormal reading is due to instrument error. Any other cause must be traced to its source.

Because of the safety factor commonly incorporated in pumps and similar equipment, considerable loss of capacity can occur before any external evidence is apparent. Changes in the operating speeds (from those normal for the existing load) of pressure-governor-controlled equipment should be viewed with suspicion. Most variations from normal pressures, lubricating oil temperatures, and system pressures indicate either inefficient operation 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 whether there is any danger that a similar failure might occur in other units. The cause of the failure must also be determined and corrected in order to avoid repeated failure of the same or similar components. Prompt inspection may eliminate a wave of repeated casualties.

Strict attention must be paid to the proper lubrication of all equipment, including frequent inspection and sampling to ensure that the correct quantity of the proper lubricant is in the unit. It is good practice to make a daily check of samples of lubricating oil in all auxiliaries. Such samples should be allowed to stand long enough for any water to settle. When auxiliaries have been idle for several hours, particularly overnight, a sufficient sample to remove all settled water should be drained from the lowest part of the oil sump. Replenishment with fresh oil to the normal level should be included in this routine.

The presence of saltwater in the oil can be detected by drawing off the settled water by means of a pipette and by running a standard chloride test. A sample of sufficient size for the test can be obtained by adding distilled water to the oil sample, shaking it vigorously, and then allowing the water to settle before draining off the test sample. Because of its corrosive effects, saltwater in the lubricating oil is far more dangerous to a unit than is an equal amount of freshwater. Saltwater is particularly harmful to units containing oil-lubricated ball bearings.

The information given so far relates to the inspections that Enginemen make on operating engines (either diesel or gasoline). Since the Navy uses more diesel than gasoline engines the remainder of this chapter will deal with diesel engines and with the inspection and maintenance procedures that are required by the planned maintenance system (PMS) and the manufacturers' technical manuals.

COMPRESSION AND FIRING PRESSURES

Readings of the compression and firing pressures must be taken every 200 hours for the trend analysis graphs. They may also be taken at other times when engine operating conditions require additional monitoring such as when an engine misfires, fires erratically, or when any one cylinder misfires regularly. There can be many reasons for an engine to misfire, some of these are a clogged air cleaner/filter, an engaged fuel cutout mechanism, or a loss of compression. If, after checking the air cleaner, the filter, and the fuel cutout mechanism, you determine that the problem is due to loss of compression, then you must perform a compression check with a cylinder pressure indicator.

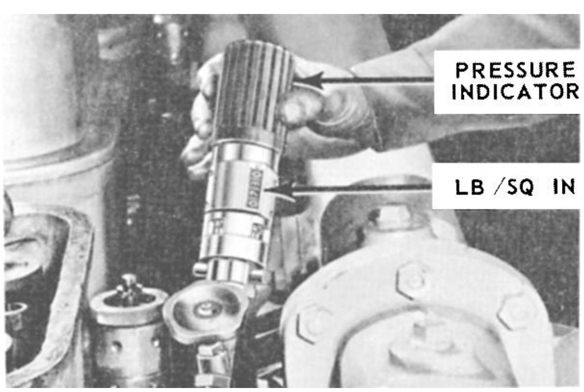
There are several different types of indicators that may be used. Most indicators used with diesel-cylinder engines are either of the spring balanced type or the trapped pressure type. They are manufactured by various companies such as Kiene, Bacharach, and Kent-Moore. Some of these indicators measure only compression pressure, others measure both compression and firing pressures.

Spring Balanced Indicator

A spring balanced indicator, such as the one manufactured by Bacharach (figure 3-1), employs a spherical ball piston, which is held on its seat by the force of a helical spring actuated by the cylinder pressure which acts against the bottom of the ball piston to oppose the spring tension. Before the indicator is attached to the engine, the vulcanized handle must be rotated clockwise until the reading on the counter is greater than the maximum cylinder pressure expected. The amount of this pressure is listed in the engine manufacturer's technical manual. When the indicator is installed, the operator must make sure that it is placed as near the cylinder as possible and position it so that it can be read easily. After the indicator is installed the engine is operated at the specified rpm, then the fuel to the cylinder being tested is cut out, the cylinder test cock is opened, and the spring tension on the indicator is adjusted. The tension of the spring is reduced by rotating the vulcanized handle counterclockwise until the maximum cylinder pressure barely offsets the spring pressure. At this point, the latch mechanism of the indicator trips and locks the handle firmly in position, giving a direct and exact reading of the pressure in pounds per square inch (psi). To reset the lock mechanism for a new reading, the handle must be rotated counterclockwise one-fourth turn. When this indicator is stowed for future use, the indicator spring must be unloaded by rotating the handle counterclockwise until a zero pressure reading is obtained.

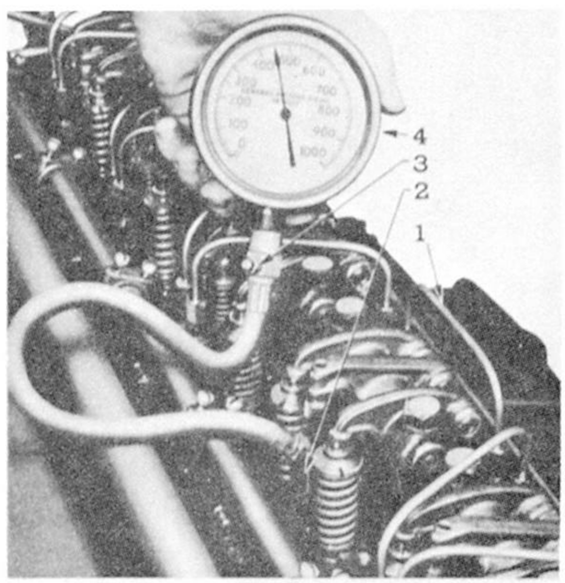
Trapped Pressure Indicators

In this type of indicator, the cylinder gases enter past a valve into a chamber which leads to a gage. When the pressure above the valve equals that of the cylinder, the valve seats and traps the gas above the valve at its highest pressure, then this pressure is read on the gage. There are several other types of indicators. The one pictured in figure 3-2 is used to take compression readings



75.238X
Courtesy of Bacharach, Inc., USA

Figure 3-1.-Spring balanced Pressure Indicator.



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Courtesy of Bacharach, Inc., USA

Figure 3-2.—Trapped Pressure Indicator (small boat).

only on engines installed on small boats. Engines like the GM-6-71 do not have indicator cocks installed.

When taking compression readings on a 6-71 engine, you will perform the following steps:

1. Check the manufacturer's technical manual for the minimum compression pressure required for the engine.

2. Start the engine and run it at approximately one-half the rated load until normal operating temperatures are reached.

3. Stop the engine and remove the fuel pipes from the injector and the fuel connectors on the cylinder to be tested.

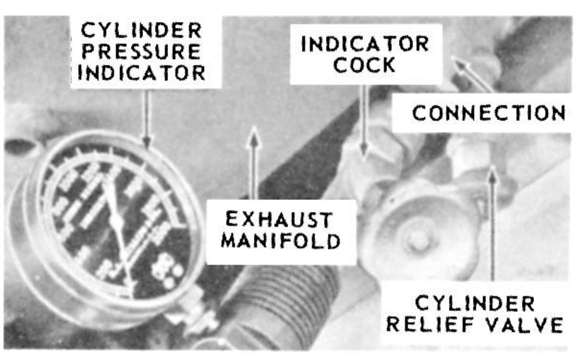
4. Remove the injector and install the indicator adapter, with pressure gage attached, and use the crab nut to hold the adapter in place.

5. Use a space fuel pipe to fabricate a jumper connection between the fuel inlet and the return manifold connectors to by-pass fuel to and from the injector.

6. Start the engine again and run it at approximately 600 rpm.

7. Observe and record the compression pressure as indicated on the gage.

Another type of trapped pressure indicator is the Kiene indicator (figure 3-3). This indicator is basically a Bourdon gage connected to a cylindrical pressure chamber. The pressure chamber contains a check valve which allows the gas to flow from the engine into the chamber until the pressures are equalized. This gage is attached to the chamber and the pressure is read directly. The check valve is an inverted piston seating on a seat piece. The valve moves up and down in a guide. A stop nut is used to adjust the travel of the check valve.



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Courtesy of Bacharach, Inc., USA

Figure 3-3.—Trapped Pressure Indicator.

Most of you should become familiar with this indicator since it is widely used to check both the compression and firing pressures on main diesel engines and emergency generator diesel engines. Review figure 3-4A and B. It is a PMS situation requirement to be performed when the engine operating conditions indicate problems.

EXHAUST AND CYLINDER TEMPERATURES

One of the most useful tools that the engine operator has for monitoring an engine's performance is the thermocouple pyrometer. The principal use of this device is in the exhaust system (but it can also be used for other purposes) where it is used to measure the exhaust gas temperatures at each cylinder or the common temperature in the exhaust manifold. By comparing the exhaust gas temperatures of each cylinder, the operator can determine if the load is balanced throughout the engine.

The two types of pyrometers in use are the fixed installation and the portable hand-held instrument (figure 3-5). Both types use a thermocouple unit, such as the one shown in figure 3-5, installed in the exhaust manifold.

In its simplest form, a thermocouple consists of two dissimilar metal wires, usually iron and constantan (55% copper and 45% nickel) that are joined at both ends to form a continuous circuit. When the temperatures at the junctions are different an electrical current is produced and flows in the circuit. The greater the temperature difference, the greater the voltage produced.

One junction, known as the hot junction, is contained in a closed-end tube, installed in the exhaust manifold of each cylinder. The other junction called the cold junction, is exposed to room temperature, and is located at the pyrometer wire

SHIP SYSTEM	SUBSYSTEM	MRC CODE	
		A-2 R-5	
SYSTEM	**EQUIPMENT** Emergency Generator Diesel Engine	**RATES** EN1 EN3	**M/H** 1.0 1.0
MAINTENANCE REQUIREMENT DESCRIPTION 1. Measure compression and firing pressures.		**TOTAL M/H** 2.0 **ELAPSED TIME** 1.0	

SAFETY PRECAUTIONS

1. Forces afloat comply with Navy Safety Precautions for Forces Afloat, OPNAVINST 5100 series.
2. Wear gloves when handling indicator.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. Kiene indicator
2. Asbestos gloves
3. Pencil and paper
4. Injector lockout wrench, mfr part No. 3385742

PROCEDURE

NOTE: Accomplish when directed as result of engine operating condition.

Preliminary

a. Ensure engine is at normal temperature and operating at full speed and no load.

1. **Measure Compression and Firing Pressures.**
   a. Measure compression pressures.
      (1) Remove cover from cylinder being tested.
      (2) Open cylinder test cock to blow out passage; shut test cock.

WARNING: Wear gloves when handling indicator.

(3) Attach indicator to test cock.
(4) Install lockout wrench and lock out the injector.
(5) Open indicator vent and cylinder test cock.
(6) Shut indicator vent and adjust indicator for minimum vibration.
(7) Record compression pressure and shut cylinder test cock; normal compression pressure is 550 psi to 650 psi.
(8) Remove injector lockout wrench.
(9) Repeat steps 1.a.(2) through 1.a.(8) for each remaining cylinder under cover removed in step 1.a.(1), if applicable.
(10) Reinstall cylinder cover.
(11) Repeat steps 1.a.(1) through 1.a.(10) for remaining cylinders.

b. Operate engine at full speed and full load.
c. Measure firing pressures.

LOCATION	DATE May 1980

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MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV 4700 1 ( ) (Rev)

Figure 3-4A.—MRC-for measuring compression and firing pressures (front).

PROCEDURE (Cont'd)

(1) Open No. 1 cylinder test cock and blow out test cock; shut test cock.
(2) Install indicator.
(3) Open cylinder test cock and record firing pressure; maximum firing pressure is 900 to 1100 psi.
(4) Shut cylinder test cock and vent the indicator.
(5) Remove indicator from test cock.
(6) Repeat steps 1.c.(1) through 1.c.(5) for remaining cylinders.

d. Stop engine and line up for automatic operation.

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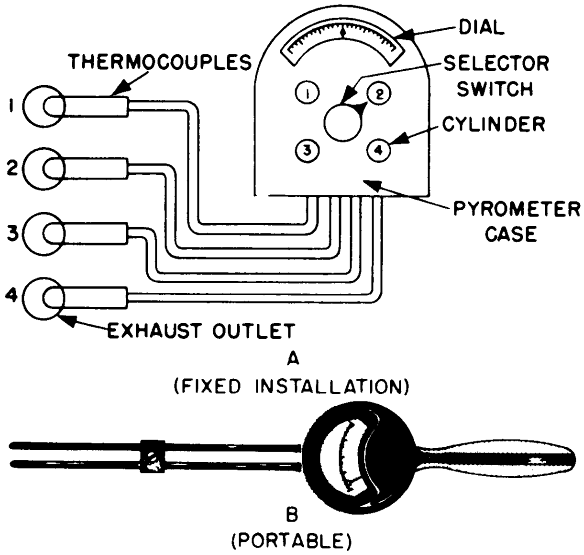
MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV 4700 1 ( ) (Rev)

Figure 3-4B.—MRC-for measuring compression and firing pressures (back).



75.170

Figure 3-5.—Pyrometers used in diesel exhaust systems.

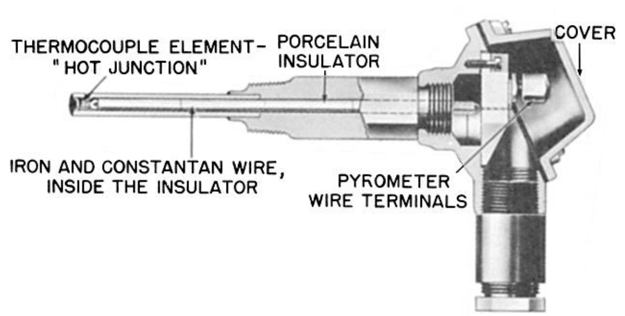


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Figure 3-6.—Sectional view of a thermocouple.

terminals (see figure 3-6). A pyrometer (millivolt meter) measures the voltage produced and shows the results on a scale which has been calibrated to read in degrees of temperature. In fixed installation pyrometers, if the connecting wires are of the same type as those of the thermocouples, the thermocouple element becomes, in effect, extended to the pyrometer terminals and the temperature at the meter (now the cold junction) becomes the reference temperature. Then the selector switch can be rotated to any cylinder and contact can be made between the pyrometer and the hot junction. A reading can then be obtained for that particular point.

The hand-held pyrometer consists of an indicator and a pair of pointed prods attached to a sub-base and supported by a handle. To obtain a reading, the prod points are pressed against the exposed thermocouple terminals. The reading is taken from the scale. A point to remember is that the zero adjuster must be set to indicate room temperature rather than 0° temperature.

GRAPHIC RECORDS

As you read in chapter 2, graphic records play an important part in keeping an engine in proper operating condition. When used properly they can tell you how your engine is performing and what is happening inside the engine. Graphic records indicate the overall condition of an engine and warn you when certain parts are beginning to wear out so that you may take prompt corrective actions and prevent major casualties.

ADJUSTMENT AND MAINTENANCE

An internal combustion engine is a complicated machine, built with a high degree of precision throughout and capable of long dependable service if it is kept in good operating condition.

To keep an engine in good operating condition you must perform all the adjustments and maintenance prescribed in your installed PMS and the manufacturers' technical manuals. In this section you will read about the adjustment and maintenance of various components of an internal combustion engine.

AUTOMATIC REGULATING VALVE

In many engines, freshwater temperature is regulated by an automatic regulating valve which maintains the freshwater temperature at any desired value by bypassing a portion of the water around the freshwater cooler. An automatic temperature regulator of the type commonly used in the cooling systems of marine engines is shown in figure 3-7. Even though these regulators are automatic (self-operated), provisions are included in most installations for manual operation in the event that the automatic feature fails.

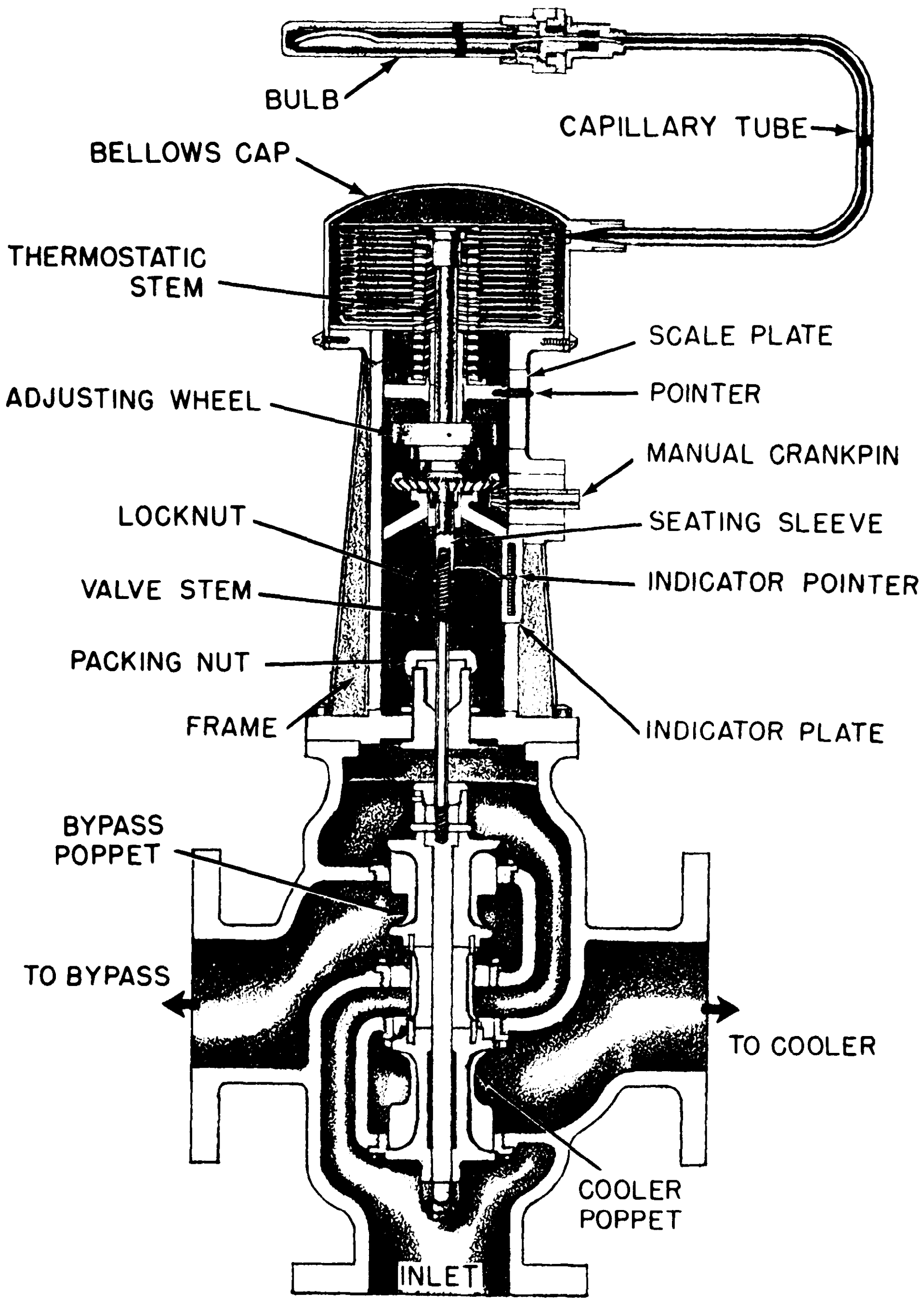

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Figure 3-7.—Automatic temperature regulator.

The temperature regulator consists of a valve and a thermostatic control unit mounted on the valve. The thermostatic control unit consists of a temperature-control element and a control assembly.

The temperature-control element is essentially two sealed chambers consisting of a bellows connected by a flexible armored capillary tube to a bulb mounted in the engine cooling-water discharge line. One chamber is formed by the bellows and cap, which are sealed together at the bottom; the other chamber is in the bulb. The entire system (except for a small space at the top of the bulb) is filled with a mixture of ether and alcohol which vaporizes at a low temperature. When the bulb is heated, the liquid vaporizes and the pressure within the bulb increases. This forces the liquid out of the bulb and through the capillary tube to the bellows. As the bellows is moved down, it operates the valve.

The control assembly consists of a spring-loaded mechanical linkage which connects the temperature-control element to the valve stem. The coil spring in the control assembly provides the force necessary to balance the force of the vapor pressure in the temperature-control element.

Thus, the downward force of the temperature-control element is balanced, at any point, by the upward force of the spring. This permits the valve to be set to hold the temperature of the engine cooling water within the allowed limits.

The regulator operates only within the temperature range marked on the nameplate; it may be adjusted for any temperature within this range. The setting is controlled by the range-adjusting wheel, located under the spring seat. A pointer attached to the spring seat indicates the temperature setting on a scale which is attached to the regulator frame. The scale is graduated from 0 to 9, representing the total operating range of the regulator.

The location of a temperature regulator may be located in either the seawater or freshwater circuit. In most engines, the regulator is located in the freshwater circuit.

When located in the seawater circuit, the regulator controls the amount of seawater flowing through the coolers. As the temperature of the freshwater becomes greater than the temperature for which the regulator is set, the regulator actuates a valve to increase the flow of seawater through the coolers. On the other hand, when the freshwater temperature is below the temperature for which the regulator is set, the regulator actuates the valve and decreases the flow of seawater through the coolers.

In installations where the regulator is in the freshwater circuit, water is directed to the cooler when the temperature of the water is above the maximum setting of the regulator. After passing through the cooler where the temperature of the water is lowered, the water returns to the suction side of the freshwater pump to be recirculated. When the temperature of the water is below the maximum setting of the regulator, the water bypasses the cooler and flows directly to the suction side of the pump. Bypassing the cooler permits the water to be recirculated through the engine; in this way, the temperature of the water is raised to the proper operating level.

Regardless of whether the regulator is in the fresh or seawater circuit, the bulb which causes the regulator to operate is located in the freshwater discharge line of the engine.

Temperature regulators not only control the temperature of the freshwater but also control indirectly the temperature of the oil discharged from the lubricating oil cooler. Control of the lubricating oil temperature is possible because the water (freshwater or saltwater) that is passed through the regulator and the freshwater cooler is also the cooling agent for the lubricating oil cooler. When the lubricating oil is cooled by seawater, two temperature regulators are installed in the seawater circuit. The temperature regulator bulb of the regulator that controls the temperature of the freshwater is installed in the freshwater circuit; the bulb of the regulator that controls the temperature of the lubricating oil is installed in the lubricating oil system.

Maintenance

To allow proper operation of a temperature regulator, the valve stem must not bind in the stuffing box, but must move freely. The valve stem must be lubricated frequently where it enters the stuffing box and also around the threaded sleeve used for the manual control. A small amount of grease should also be used on the bevel

Figure 3-8.—Figure Removed.

gears. The valve packing nut should be kept only finger tight and should be lubricated occasionally with a drop of oil. Should it become necessary to renew the packing, you will need to remove the nut, take out the packing gland, clean the stuffing box, and repack it with asbestos wicking saturated with oil.

Should the temperature of the freshwater leaving the engine be too high when the regulator is set on the lowest adjustment setting you should do the following:

1. Ensure that the manual pointer is set at the THERMOSTATIC position.
2. Ensure that the packing gland is not binding the valve stem and that the valve stem is not stuck in the COOLER CLOSED (minimum cooling) position.
3. Check the water lines for other causes of the difficulty. If this check does not reveal the cause of the trouble, it is probable that the temperature control element is inoperative, and that it should be checked.

If undercooling occurs when the temperature regulator is set on the highest adjustment setting, check for a sticking valve in the BY-PASS CLOSED (maximum cooling) position. Sticking may be caused by a tight stuffing box or by dirt under the lower valve seat. If the temperature at the bulb is lower than the set temperature and the valve position indicator shows COOLER

CLOSED, excessive leakage is indicated. In such case you will have to regrind the valve using the following procedure:

1. Disconnect the valve from the piping.
2. Remove the packing nut and the packing.
3. Disconnect the valve stem and remove the locknut from the thermostatic stem.
4. Remove the thermostatic control unit from the valve.
5. Clean the valve stem until it is smooth. If necessary, polish it with fine emery cloth.
6. Grind the valve seats until a perfect seal is obtained; then remove all grinding compound from the valve and the seats.
7. Reassemble the valve and the control unit.
8. Repack the stuffing box and lubricate it with engine oil.
9. Secure the packing gland nut finger tight.
10. Insert the bulb into the ship's piping in either a horizontal or vertical position, as shown in views A and B of figure 3-9. When the bulb is installed in the vertical position, the nut must be at the top; when it is installed in the horizontal position, the arrow on the indicator disk must point upward. NEVER INSTALL THE BULB WITH THE NUT AT THE BOTTOM (as shown in view C of figure 3-9) because in this position the liquid would be below the end of the internal capillary tube and would have little or no effect on the bellows of the temperature regulator valve.
11. Adjust the regulator.

Adjustment

A closeup of the adjusting and indicating features of the temperature regulator is shown in figure 3-10. The procedure for adjusting a temperature regulator is as follows: Rotate the manual crank pin until the indicator pointer is in

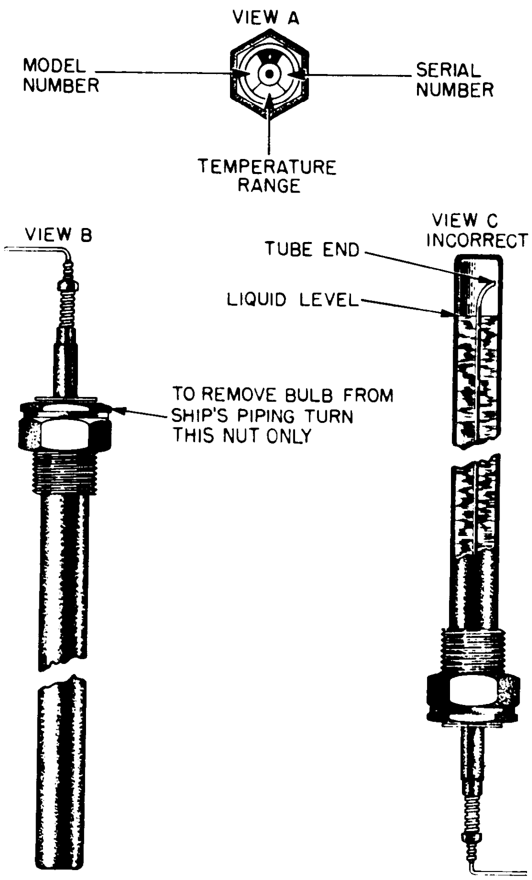

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Figure 3-9.—Bulb installation.

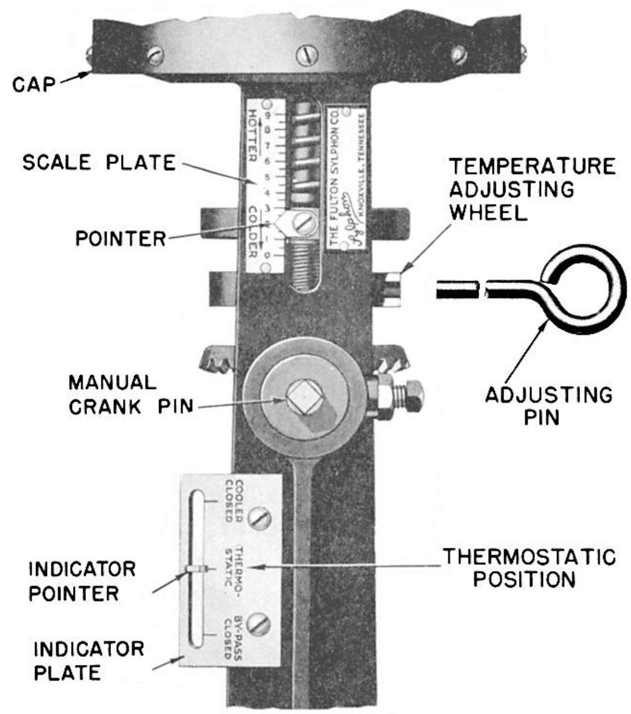

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Figure 3-10.—Scale and Indicator plates of temperature regulator.

the THERMOSTATIC POSITION. Turn the adjusting wheel until the pointer is opposite 2 on the scale plate. Loosen the locknut and unscrew the valve stem until it is free of the thermostatic stem. Then turn the adjusting wheel until the pointer is opposite 8 on the scale plate. (Note: The preceding steps should be performed with the thermostatic bulb removed from the ship's piping and when the bulb temperature is below 100°F.)

Again rotate the manual crankpin until the lower end of the seating sleeve is flush with the lower end of the thermostatic stem. With the seating sleeve and the indicator pointer in this position, loosen the screws in the indicator plate and slide the plate up or down as needed to align the THERMOSTATIC mark in the center of the plate with the indicator pointer. Then retighten the screws. (The marks COOLER CLOSED and COOLER BY-PASS on the indicator plate are only approximate.) Screw the valve stem into the thermostatic stem and turn it until the cooler poppet valve seats firmly. Turn the adjusting wheel until the pointer is opposite 2 on the scale plate. Turn the valve stem one full turn into the thermostatic stem and retighten the locknut.

With the manual control on the THERMOSTATIC position, turn the adjusting wheel in a direction to bring the pointer to number 9 on the scale plate. Run the engine at warmup speed until the temperature of the fluid, as indicated by the thermometer in the line with the thermostatic bulb, rises to the desired temperature. (The desired temperature must be determined in advance from applicable instructions.)

With the engine running at warmup speed and the temperature at the thermostatic bulb at the desired value, turn the adjusting wheel until the cooler poppet just begins to leave its seat. This action is shown by the movement of the mark on the valve stem downward from the COOLER CLOSED mark on the valve position indicator. Valves adjusted in accordance with this procedure will normally maintain the temperature of the fluid at the thermostatic bulb between the desired value and a temperature approximately 20° higher, under any conditions of engine load or injection temperature. This 20° difference is the temperature rise required to cause the poppet valve to move through the necessary travel.

HEATING EXCHANGER DEFINITIONS

Problems with the cooling system of an engine may prevent the cooling system from keeping the engine parts and working fluids at safe operating temperatures. Failure of the system may lead to several of the troubles and casualties that have been discussed earlier.

In marine installations, lubricating oil and most of the engine parts are cooled by the circulation of seawater, freshwater, or both. When the cooling of an engine part is mostly by oil spray or oil circulation, the oil is cooled by circulation through an oil cooler. Figure 3-11 illustrates a cooling system in which both freshwater and seawater serve as coolants.

When maintaining engine cooling water temperatures within specified limits, the principal difficulties you may encounter are in maintaining circulating pumps in operating condition; preventing corrosion; reducing the cause of scale formation in water jackets and heat exchangers; cleaning jackets and heat exchangers according to proper procedures; and in preventing leaks in the various parts of the system.

The coolers (or heat exchangers) which remove the heat from the cooling water of an engine may vary considerably in design. Those used in cooling systems may be classified basically as the radiator type and the tubular type. The radiator is sometimes referred to as the strut or the Harrison type, while the tubular is identified as the Ross or shell-and-tube type. A heat exchanger of both types is shown in figure 3-12. The heat exchanger on the top of the picture is a radiator type heat exchanger; the one on the bottom is a tubular-type heat exchanger. In heat exchangers of the radiator type, the freshwater passes through the tubes and the seawater passes around them. In the tubular type, the freshwater surrounds the tubes and the seawater passes through them.

CASUALTIES

Although heat exchangers vary in design, they are all subject to similar casualties. The principal difficulties which may prevent heat exchangers from functioning properly are excessive scale deposits on the cooler element, clogged cooler elements, or cooler leakage.

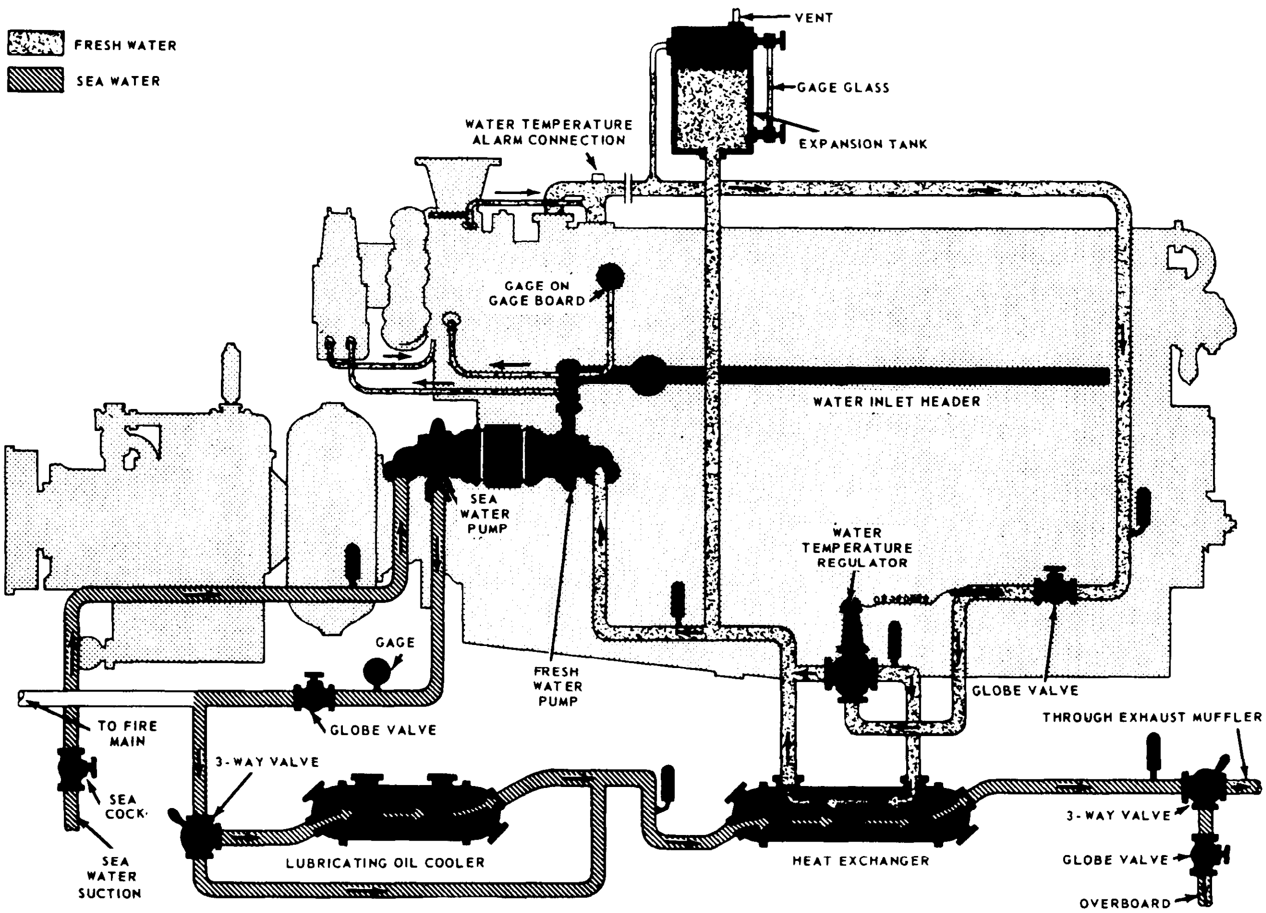

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Figure 3-11.—A cooling water system.

A gradual increase in the freshwater temperature is usually an indication of EXCESSIVE SCALE on a cooler element. As scale formation increases, there is a gradual increase in the pressure difference between the inlet and outlet of the heat exchanger. Scale deposits generally form faster on the saltwater side than on the freshwater side, because of the greater amount of dissolved salt present in the water.

Complete prevention of scale formation is not possible, but steps can be taken to reduce its formation by using proper cleaning methods and procedures. Seawater discharge temperature should be maintained below a specified limit (130°F), because the rate of scale formation is increased as the temperature increases. The water used in closed cooling systems must be as pure as possible. Distilled water is recommended for a freshwater cooling system, but since distilled water is not absolutely pure, additional steps must be taken to control acidity and alkalinity. The treatment used to control these factors will not remove scales already formed, but it will prevent further precipitation of scale-forming slats. You will find details for water treatment in closed water systems in chapter 233, *NAVSHIPS Technical Manual,* and in most engine instruction manuals.

Not only the hard deposits chemically precipitated from the circulating water, but also such items as marine life, grease, and debris of various types may CLOG OR RESTRICT COOLER ELEMENTS. The principal causes of

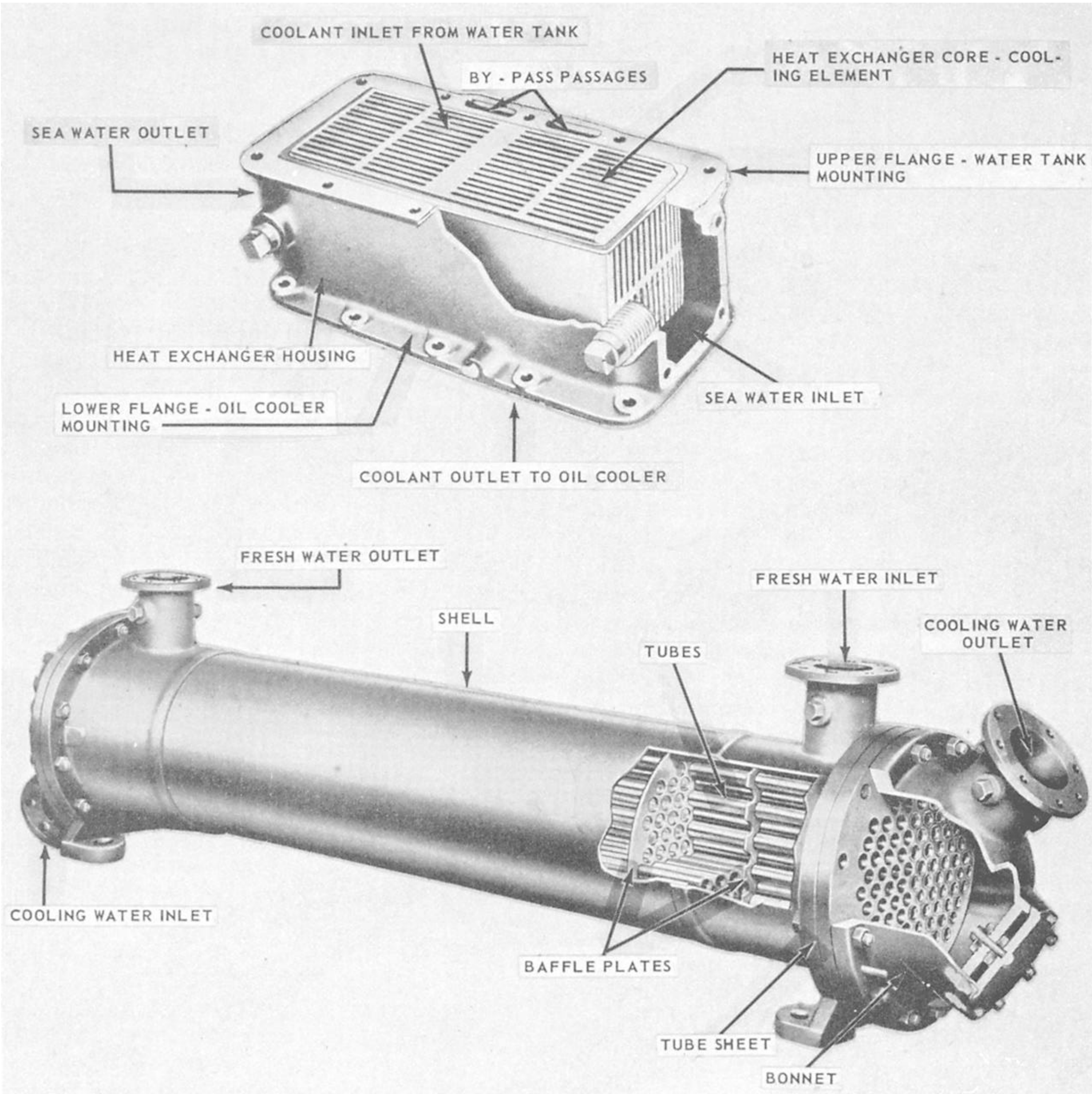

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Figure 3-12.—Types of heat exchanges.

cooler clogging by loose foreign matter are faulty seawater strainers, dirty freshwater, excessive lubrication of the pumps, and leaking oil coolers.

To prevent the entry of sea debris, a punctured screen in a seawater strainer must be replaced as soon as possible. Obviously, the use of dirty freshwater will hasten the clogging of a cooler element. Grease and oil may enter the cooling system and the film deposited on the cooler element will reduce the capacity of the cooler. Grease may come from grease cups which are used on some water pumps to lubricate bearings. If the cups are turned down too much or too often, grease is forced into the circulating water. A hole in the element of an oil cooler permits oil to flow into the cooling system. Any source of oil or grease should be located and repairs made as soon as possible.

Corrosion or erosion of the element in a heat exchanger, as well as operation at excessive pressure, may cause LEAKS. These leaks can develop either in the element or in the casing. Leakage from the cooler casing can usually be detected by inspection. Element leaks, however, are more difficult to detect. Any noticeable decline or rise in the freshwater tank level, with the temperature remaining normal, usually indicates leakage.

A hole made by corrosion in a cooler element indicates that corrosion probably exists throughout the element, and a thorough inspection should be made. Corrosion can be prevented to a large extent by using the prescribed freshwater treatment, inspecting as necessary and venting the cooler to remove entrapped air.

Holes due to erosion are usually caused by particles of grit (sand, dirt, etc., resulting usually from operation in shallow water) striking an element at high velocity. Grit is for the most part so fine that it passes easily through the strainer. If the strainer is defective, even the larger particles of grit may enter the cooler.

Erosion by water at high velocity may also result in holes in a cooler element. This occurs when water flow has to be increased above the rated capacity in order to maintain a desired freshwater temperature. Whenever it is found necessary to greatly increase the water flow, the cooler should be cleaned.

If the designed maximum operating pressure (indicated on the exchanger name plate) is exceeded, leaks are apt to result. Excessive pressure is likely to occur in conjunction with clogging, because additional pressure is necessary to force a given quantity of water through a clogged element.

MAINTENANCE AND REPAIR

Because of the difference in their construction, methods of cleaning both types of heat exchangers (radiator and tubular) differ in some respects. Radiator-type heat exchangers are cleaned by chemical means because mechanical cleaning is not satisfactory for this type heat exchanger. Chemical cleaning of radiator-type units is discussed in *Engineman 3 & 2*, NAVEDTRA 10541 (current edition). Tubular heat exchangers, on the other hand, are cleaned by mechanical means.

In both types of heat exchangers, loose foreign matter such as seaweed, sand, and dirt may be removed by blowing steam through the element in a direction opposite to the normal flow of water. When an element is badly clogged, care must be exercised not to admit steam at a pressure exceeding the maximum specified for the element. If a film of oil or grease is evident, the element should be cleaned like an oil cooler element.

Leakage from the CASING of a radiator-type heat exchanger may be caused by a damaged gasket. If so, the heat exchanger should be removed from the piping in order that flange faces may be tightened evenly after a new gasket is installed. If there is any reason to suspect that there are leaks in a heat exchanger element, the best method for locating them is by an air test. This test may be accomplished as follows:

1. Remove the element from the casing.
2. Block off the discharge side of the element.
3. Attach a pressure gage to the inlet line of the element.
4. Supply low-pressure air to the inlet side of the element. Remember: <u>Air pressure must NEVER exceed design pressure for the element.</u>
5. Immerse the element in a tank of water.
6. Check for bubbles.

An element of a heat exchanger may also be tested hydrostatically by filling the element with water under pressure and checking for leaks.

Emergency repair of leaks in the element of a radiator-type heat exchanger can be made as shown in figure 3-13. When emergency repairs to the radiator-type heat exchanger are necessary, they may be made with the use of soft solder and a small torch or soldering iron. Extreme care must be taken to prevent the surrounding area from being overheated, thus causing the existing solder to melt. Small radiator-type heat exchangers

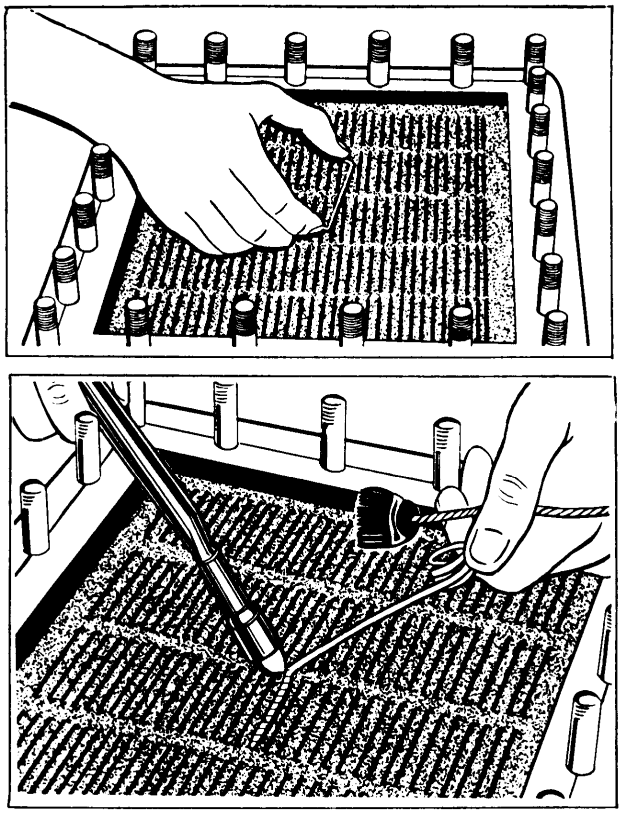

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Figure 3-13.—Emergency repair of a tube leak in a radiator type heat exchanger.

should be replaced as soon as a leak develops, if a replacement is available. The presence of one leak, unless caused by dropping or accidental puncture, indicates that other areas in the heat exchanger may be eroded.

In shell-and-tube heat exchangers, a leaking tube must be replaced as soon as possible. In an emergency, a faulty tube may be blocked off by inserting a special plug at each end, until the tube can be replaced. An air lance or water lance should be used to clean the tubes of a shell-and-tube heat exchanger. If the scale has hardened in the tubes, a round bristle brush or soft rubber plugs may be used to clean the tubes. When cleaning the tubes by mechanical means, avoid damaging the protective coating inside the tubes. These tubes should never be polished, as the tarnish on the tubes acts as insulation to prevent further corrosion. Removing the tarnish will also reduce the tube wall thickness and over a period of time and a number of cleanings, could sufficiently reduce tube strength, resulting in tube failure. For the proper procedures for cleaning shell and tube type heat exchangers and the safety precautions, use the PMS maintenance requirements cards, the manufacturer's technical manual and *Naval Ships's Technical Manual,* chapter 254.

LUBRICATING SYSTEM

To ensure that all the parts of an engine receive adequate lubrication, it is essential that all parts of the lubricating oil system be properly maintained at all times. Some parts which may be a source of trouble are considered in this section. For other information on lubricating systems, see *Engineman 3 & 2,* NAVEDTRA 10541 (current edition).

LUBE OIL PUMPS

Pumps used in engine lubricating systems are of the positive displacement type. In some pumps pressure control is maintained by pressure regulating or pressure relief valves built directly into the pump; in other pumps, valves exterior to the pump are used for this purpose. Most regulating devices recirculate excess lube oil back to the suction side of the pump, but some pumps discharge excess oil directly into the engine sump.

Pump casualties, as well as many other lube systems failures, are indicated by the loss of lube oil pressure. The loss of oil pressure can be recognized by checking the pressure gages at prescribed intervals, or by means of an electrical alarm system. Most lube oil pump failures are generally due to wear, and develop gradually. Failures may also occur abruptly if a drive shaft breaks, or some parts suffer physical deformation. Such failures are usually indicated by abnormal noise in the pump and by sounding of the low-pressure lube oil alarm.

The warning system should be tested at specified intervals, usually when an engine is being started or secured. Warning systems do not excuse personnel from their responsibility for keeping a vigilant and accurate watch on engine instruments. The instruments give the most reliable indication as to what an engine is doing and what adjustments should be made.

OIL LINES AND PASSAGES

Troubles occurring in the oil passages and oil lines are usually in the form of plugged or cracked lines. The former is generally the result of carelessness, while the latter is usually a result of improper support of the line.

Even though clogged passages may be indicated by increased pressure gage readings, it is dangerous to rely wholly on such indications, since stoppage occurring beyond the pressure regulating valve and pressure gage may cause very little, if any, pressure increase on the gage. You can best determine if a bearing is receiving oil by inspecting it occasionally, just after engine shut-down. There should be plenty of oil in the vicinity of the parts being lubricated. Another method for checking bearing lubrication is to note the temperature of the bearings by feeling them with the hand after engine shut-down. You should be able to keep your hand on them for at least a few seconds.

You can help prevent most oil line stoppage by observing the following rules:

1. Never use cotton waste or paper towels for cleaning an engine. They may leave lint or small bits of material which later may collect in the lines.
2. Service the oil filters at specified intervals. Clean the case properly and when the lines are removed, blow them out with compressed air.

FUEL INJECTION EQUIPMENT AND CONTROLS

The fuel system is one of the most complicated of all engine systems; therefore, special care must be exercised when making adjustments and repairs. Even though manufacturers have designed many different fuel systems, the basic principle involved is the same in all of them. If you understand the basic principle for one system, you will have no difficulty in becoming familiar with other systems. The procedures for the maintenance and repair of the various systems are also similar.

Let's review briefly not only the function of a fuel system but also the various types of fuel systems. As you know the function of a fuel injection system is to deliver fuel to the engine cylinders under specific conditions: at a high pressure, at the proper time, in the proper quantities, and properly atomized. This function may be carried out by either one of two types of systems: the air injection type or the solid injection type. Since there are few air injections systems now in use, we will consider only the solid (mechanical) injection type systems.

Solid injection systems may be classified as jerk pump systems and common rail systems. Variations are to be found in each of these systems. The following examples show some of the basic differences between the various solid injection systems.

Systems of the JERK PUMP type may be identified as either individual pump systems or unit injection systems. Some jerk pump systems use a separate pump and fuel injector for each cylinder, while the unit injection systems combine the pump and injector into a single unit.

The Bosch system is an example of an individual pump system. The pump is a cam-actuated, constant stroke, lapped plunger and barrel pump. The pump times, meters, distributes, and provides the necessary pressure to inject the fuel into the cylinder through a separate nozzle.

The General Motors unit injector is an example of a unit injection system. It embodies a cam-actuated, constant stroke, lapped plunger and bushing, a high pressure pump, and an injection nozzle, all in one unit.

In the Cummins injection system, a cam-actuated injector and nozzle assembly is mounted in each cylinder. This system employs a common metering device that distributes a measured quantity of fuel to each of the injectors. The Cummings injection system embodies characteristics of the unit injector and is sometimes classified as such, although it is also called a distributor system.

The Fairbanks-Morse injection system is another example of a jerk pump system.

The injection system known as the COMMON RAIL system includes two types: the basic common rail system and the modified common rail system.

The fuel injection systems used on Atlas engines and some older models of Cooper-Bessemer engines are of the basic type. In this system one untimed, high-pressure pump supplies fuel at injection pressure to a main header (common rail). The fuel flows from the header to the injector valves and nozzles at each cylinder. The injector valves are cam-operated and timed. Metering of the fuel is controlled by the length of time the nozzle remains open and by the pressure maintained by the high-pressure pump in the common rail.

The modified common rail system (constant pressure), found on newer models of Cooper-Bessemer engines, uses a high-pressure pump to maintain fuel at the injection pressure in an accumulator bottle. The fuel is metered by individual valves mounted on the side of the engine; it then flows to the pressure-operated nozzles in the cylinder head, to be atomized and distributed in the cylinder.

Since complete details for the maintenance and repair of each of the various fuel systems in service are beyond the scope of this book, specific information on a particular fuel injection system must come from the appropriate manufacturer's technical manual.

FUEL INJECTION PUMPS AND INJECTORS

In any discussion of a fuel system, the importance of each of its parts cannot be overlooked. The first requirement for trouble-free operation of a fuel system is clean fuel. Accordingly, the filters, the strainers, the tanks, the transfer pumps, and the lines must be maintained according to prescribed instructions. Even when these parts function properly, the principal elements of the injection system—pressure pump, injection valves, and injection nozzles—are subject to troubles. The following discussion covers some of these troubles, their symptoms and causes, and provides general information concerning maintenance and repair of this equipment. As you study this information, keep in mind the differences which may exist between the various systems. (A system, for example, may be of the jerk pump or common rail type, or the pressure pump and the injector may be separate or combined.)

Damaged Plunger

In the plunger and barrel assembly of a high-pressure pump and in the plunger and bushing assembly of a unit injector, the symptoms and causes of damage are similar.

Damage may become apparent through erratic engine operation. Symptoms vary widely and may include failure of the engine to develop full power, low exhaust temperature, low firing pressure for the affected cylinder, difficulty in balancing (calibrating) the pumps or injectors, and failure of one or more cylinders of the engine to fire. Damage to a plunger and the part in which it slides may also be recognized by testing the unit on a test stand. However, the best way to determine the extent of damage is to disassemble the unit, clean it thoroughly, and then carefully inspect each part.

Cleaning of the units can be best accomplished by use of an approved solvent. Clean diesel fuel may be used when more effective cleaners are not available. A brush must be used with diesel fuel and even then, removal of gummy deposits is difficult. Keep each plunger and barrel (bushing) together during the inspection to avoid improper assembly, as they are manufactured in matched sets.

The use of a magnifying glass during the examination of a plunger will facilitate the detection of damage. Inspect for fine scratches, dull surface appearance, cracks, pit marks (usually accompanied by dark discoloration), and erosion and roughness at the edge of the helix or at the end of the plunger. An example of a badly scored plunger is illustrated in A of figure 3-14. A plunger with the lapped surface and helix edge in good condition is shown in B of figure 3-14. Surface irregularities in the region illustrated are serious because they affect metering and, consequently, engine operation.

When examining a barrel or bushing, search for erosion of the ports or scoring of the lapped surfaces. Pay particular attention to the lapped plane surface at the end of a pump barrel. Rust or pit marks on this surface must be removed by lapping before reassembly.

Figure 3-14.—A damaged and serviceable plunger.

Damage to the plunger of a fuel injection pump or injector may be caused by such different factors as entry of dirt into the equipment, careless handling while the equipment is disassembled, corrosion, and improper assembly and disassembly procedures.

Dirt and water are responsible for practically all trouble encountered with fuel injection equipment. If the units are not properly protected, they can be damaged beyond repair within a very short period of operation. Remember that the clearances between the lapped surfaces are so small that occasionally extremely fine particles, such as dust from the atmosphere, are capable of scoring these surfaces. Then small amounts of water that may collect from condensation will corrode these surfaces.

An engine should never be operated unless the fuel has been properly filtered before reaching the injection equipment. Although regular filters and strainers are present in all fuel systems, in some systems special safety filters or screens are incorporated to further reduce the possibility of foreign matter mixing with the fuel as it reaches the pump and the injector. The location of these additional safety devices depends upon the system. In one system a screen is placed between the fuel transfer pump and the fuel distributor, while in another a filter is mounted directly on the pump.

During the overhaul of fuel injection equipment, a spotlessly clean working space is essential for the protection of all parts. Ideally, the area should also be air conditioned. All air should be thoroughly filtered before it enters the space. Benches should have smooth tops. Metal-topped benches should be covered with linoleum or lint-free rags. Ample quantities of approved cleaning solvent, of clean fuel oil, and of compressed air to blow parts dry, should be used to help ensure cleanliness during overhaul. Never use rags or waste to clean injectors, as lint particles from them may damage the injector parts.

From the time a unit is removed from the engine until it is replaced on the engine, extreme care must be exerted to keep dust and dirt away from all its parts. Before any connections are loosened, all dirt should be removed from the unit, tubing, and fittings by washing. After removal of the unit from the engine, all opening (pump, nozzle, tubing, or injectors) should be covered with approved caps or coverings.

Because many surfaces of the parts of pumps and injectors are lapped to extremely accurate finishes, it is essential that they be HANDLED WITH GREAT CARE. Parts that are dropped may be bent, nicked, dented, or otherwise ruined. All work should be done well over the center of the bench. The use of a linoleum covering will reduce casualties caused by dropping parts on the bench. Never leave parts uncovered on the bench, but keep them immersed in diesel fuel until handled. Never handle lapped surfaces when they are dry, as the perspiration on your hands may cause corrosion. Before a lapped surface is handled, it should be immersed in clean diesel fuel, and the hands rinsed in clean fuel. Since the mating parts of pumps and injectors are fitted to one another, such parts as plunger and barrel should be kept together to avoid interchanging.

Since water in the fuel, or improper storage of parts, can also cause CORROSION of the parts of a pump or an injector, all fuel should be centrifuged, and filter and strainer cases drained periodically to prevent excessive collection of water. Information on proper stowage procedures should be obtained from the appropriate technical manual.

Special care must be exercised in DISASSEMBLING and ASSEMBLING the parts of a fuel injection system, since any damage to these finely finished surfaces will necessitate replacement of the parts. When work is being done on any part of a fuel injection system, the procedure outlined in the engine technical manual, or the manufacturer's fuel system technical manual, must be followed.

Remember that the damage to a plunger and barrel assembly of a fuel pressure pump or to the plunger and bushing assembly of a unit injector generally requires replacement of the parts. A damaged part may not be replaced individually. A plunger and its mating part (barrel, bushing, or bore) must be installed as a complete assembly.

External Leakage

Trouble caused by external leakage from an injection pump or an injector may become sufficiently serious to cause an engine to misfire. It is of extreme importance that signs of external leakage be detected as soon as possible. Leakage outside of the combustion space may be sufficiently large not only to affect engine operation but also to create a fire hazard. External leakage of a unit injector can cause fuel dilution of the engine lube oil, reduce lubrication, and increase the possibility of a crankcase explosion.

In general, external leakage from pumps and injectors is caused by improper assembly, loose connections, faulty gaskets, damaged threads and sealing surfaces, broken springs, or cracked housings or bodies. While leakage from pumps is generally visible during engine operation, leakage from an injector may not become apparent until appropriate tests are performed.

You can stop the external leakage from a pump or injector either by tightening loose connections or by replacing the damaged parts. Before the equipment is inspected for leakage, thoroughly clean all parts. On some equipment, you may eliminate mild roughness or discoloration of the sealing surfaces by lapping.

Stuck Plunger

When the cylinder of an engine fails to fire, it is an indication that the injection pump plunger is stuck. Misfiring may occur intermittently if the plunger sticks and releases at intervals. Upon disassembly, it may be difficult to remove the plunger. Sometimes the plunger may stick when the pump or the injector is assembled, but will work smoothly when the unit is disassembled. At times, the plunger will not stick until some time after the unit has been removed from the engine. This is particularly true when the plunger and mating part have been stored under conditions that cause corrosion, or when the parts have been mishandled after removal.

A unit injector may be checked, after removal from the engine, by performing the binding plunger test. This test is performed by depressing the plunger, either by hand or by using the "popping" fixture of a test stand, and noting the return action of the plunger. The plunger should return with a definite snap. This test should be performed at three successive rack settings. A sluggish return action indicates a sticky plunger.

A sticking plunger may be caused by dirt, gummy deposits in the unit, or distortion of the plunger and its adjacent part.

The movement of a plunger may be restricted or entirely prevented by small particles of dirt which may lodge between the plunger and its mating surface. Lacquer-like deposits, from fuel, will also interfere with the movement of the plunger.

The greatest care must be taken when handling the parts of a pump or injector. Because of the extremely close clearances between plunger and mating surfaces, a slight distortion of either will cause binding. Distortion may result from dropping, from striking the plunger and a mating part, or from improper assembly.

Stuck plungers in fuel pumps or injectors should be freed or replaced. Sometimes a little cleaning may eliminate the need for a replacement. The plunger and barrel or bushing assembly should be soaked in an approved cleaning fluid. The assembly should be soaked overnight, or longer if necessary. Cleaning fluids approved for this purpose will immediately soften and remove any paint or enamel with which they come in contact. These fluids should be used with care, since they will damage rubber gaskets.

The specific procedures for cleaning fuel injection equipment, although similar, vary to some degree, depending upon the unit involved and the manufacturer. The following brief description of the procedures for equipment made by two different manufacturers emphasizes some of these similarities, and further emphasizes the need for following only the procedures indicated in the appropriate manufacturer's technical manual.

A plunger of a Bosch fuel injection pump can be loosened by cleaning. However, if the plunger does not slide freely in the barrel, both the plunger and barrel should be cleaned with an approved cleaning fluid, rinsed in clean fuel oil, and blown dry with compressed air. A small quantity of mutton tallow should then be placed on the plunger. Working the plunger back and forth and rotating it in the barrel should remove all gummy deposits. Instructions for Bosch fuel injection equipment state that such items as hard or sharp tools or abrasives of any kind should never be used in cleaning the pumps.

Freeing the sticking plunger in a GM unit injector may be done in much the same manner as in a Bosch pump.

Stains on plungers may be removed by the use of a limited quantity of jewelers' rouge on a piece of soft tissue paper. It is important to remember that the plunger should not be lapped to the bushing with an abrasive such as jewelers' rouge. After a plunger has been cleaned with jewelers' rouge, it must be cleaned thoroughly with diesel fuel before being placed in the bushing. If after repeated cleanings, the plunger still does not slide freely, you may assume that either the plunger or the bushing is distorted.

The principal difference in the cleaning procedures for these two units of equipment is in the use of abrasives. If the recommended cleaning procedure for these units fails to loosen the plunger so it will slide freely, the plunger and its mating part will have to be replaced.

Broken Plunger Spring

A pump of an injector will fail when the plunger spring breaks and fails to return the plunger after injection has occurred.

Factors which contribute to broken plunger springs are failure to inspect the springs thoroughly and careless handling.

Broken plunger springs must be replaced. Also they should be replaced when there is evidence of cracking, chipping, nicking, weakening of the spring, excessive wear, or when the condition of the spring is doubtful.

Jammed Fuel Control Rack

If an engine is to operate satisfactorily, the fuel control rack must be completely free to move. Since the rack controls the quantity of fuel injected per stroke, any resistance to motion will result in governing difficulties. When this occurs, the engine speed may fluctuate (decreasing as the engine is loaded; racing as the load is removed), or the engine may hunt continuously or only when the load is changed. If the fuel control rack becomes jammed, it may become impossible to control the engine speed with the throttle. The engine may even resist securing efforts under such conditions. Since a sticking fuel control rack can cause serious difficulty, especially in an emergency, every effort should be made to prevent its occurrence. The best way to check for a sticking fuel control rack is to disconnect the linkage to the governor and attempt to move the rack by hand. There should be no resistance to movement of the rack when all springs and linkages are disconnected.

A fuel control rack may stick or jam as a result of a stuck plunger, dirt or paint in the rack mechanism, a damaged rack or gear, or improper assembly. When this jamming or sticking occurs, it is necessary to determine the cause of binding. If it is due to damage, the damaged parts must be replaced; if the stickiness is due to the presence of dirt, a thorough cleaning of all parts will probably correct the trouble. Avoid errors in reassembly and adjustment by carefully studying the instructions.

Backlash in the Control Rack

Backlash, looseness, or play in the fuel control rack, like sticking or binding of the rack, will influence governing of the engine. Proper governing is based on the theory that for every change in speed of the engine, there will be a corresponding change in the quantity of fuel injected.

This is impossible if backlash, looseness, or play exists in the control system. Continuous or intermittent movement of the rack may indicate excessive looseness. Engine speed variations are also indicative of this problem. Note that even though these symptoms are characteristic of a loose rack, a governor which is dirty or out of adjustment will present similar symptoms.

Backlash in a fuel control system is generally due to a wornout gear, rack, or control sleeve. When you disassemble a pump or injector for overhaul be sure to inspect all parts of the control system for signs of excessive wear. If the rack may be moved more than a prescribed amount without moving the plunger, find the parts that are worn, and replace them.

Improper Calibration

When improper calibration (balance) of fuel injector pumps or injectors occurs, there is a difference in the amount of fuel injected into each of the cylinders. If some pumps or injectors deliver more fuel per stroke than others, the engine will be UNBALANCED; that is, some cylinders will carry a greater load than others. This condition may be detected by differences in cylinder exhaust temperatures and firing pressures, and by smoky exhaust from the overloaded cylinders. Roughness in operation and engine vibration are also indicators of an unbalanced condition.

It is important to remember that many other types of engine difficulties may cause engine symptoms identical with those due to unbalance. So when unbalance is suspected, consider first a few of the other faults that may be present such as poor condition of piston rings, inaccurate exhaust pyrometers and thermocouples, mistimed or faulty engine exhaust or inlet valves.

Improper Timing

Improper timing of a fuel system will result in uneven operation or vibration of the engine. Early timing may cause the engine to detonate and lose power. Cylinders which are timed early may show low exhaust temperatures. Late timing usually causes overheating, high exhaust temperatures, loss of power, and smoky exhaust.

Although, usually, improper fuel injection timing is caused by failure to follow the manufacturer's instructions for timing, there may be other causes for the difficulty, depending upon design of the particular systems. For example, fuel injection time in the injection pump of a Bosch system may get out of time because of a worn pump camshaft. The same problem may occur when the adjusting screw on the injector control rack of a GM system becomes loose. Either of these conditions will change fuel injection timing.

Faulty calibration and improper timing are generally due to failure to follow instructions given in the engine technical manual and the fuel injection equipment maintenance manual. These manuals should always be consulted and followed whenever timing or calibration difficulties arise.

GOVERNORS

To control an engine means to keep it running at a desired speed, either in accordance with, or regardless of, the changes in the load carried by the engine. The degree of control required depends on two factors: The engine's performance characteristics and the type of load which it drives. In diesel engines the speed and power output of the engine is determined by varying the amount of fuel that is injected into the cylinders to control combustion. There are two principal types of governors: hydraulic and mechanical.

Hydraulic Governors

It is beyond the scope of this training manual to list all of the possible troubles which may be encountered with a hydraulic governor. This section deals only with the most common ones. Poor regulation of speed may be due to the faulty adjustment of the governor or to faulty action of an engine, a generator, a synchronizing motor, a voltage regulator, or any piece of equipment which has a direct bearing on the operation of the engine.

Manufacturers state that 50% of all governor troubles are caused by dirty oil. For this reason,

Table 3-1.—Troubleshooting Chart-Governor

Trouble	Probable Cause	Corrective Action
Engine hunts or surges	Compensating needle valve adjustment incorrect	Make needle valve adjustment; ensure that the opposite needle valve is closed
	Dirty oil in governor	Drain oil; flush governor; refill
	Low oil level	Fill to correct level with clean oil
	Foamy oil in governor	Drain oil; refill
	Lost motion in engine governor linkage or fuel pumps	Repair linkage and realign pumps
	Governor worn or incorrectly adjusted	Remove governor and make internal checks for clearances according to applicable instructions
	Engine misfiring	Test and replace injectors
	External fuel linkage sticking or binding	Disconnect fuel rack from governor and manually move linkage and progressively disconnect fuel pump links until binding area is found (dirt, paint, and misalignment are the usual causes of binding)
Governor rod end jiggles	Rough engine drive	Check alignment of gears; inspect for rough gear teeth; check backlash of gear
	Governor base not bolted down evenly	Loosen bolts; realign and secure

every precaution should be taken to prevent the oil from becoming contaminated. Most hydraulic governors use the same type of oil that is used in the engine crankcase, provided it is absolutely clean and does not foam. You should change the oil in the governor at regular intervals, depending upon the type of operation, and at least every six months regardless of the operation. You must ensure that the containers used to fill the governors with oil are clean, and that only clean, new, or filtered oil is being used. You should also check the oil level frequently to ensure the proper level is maintained and that the oil does not foam. Foaming of the oil is usually an indication that water is present in the oil. Water in the oil will cause serious damage to the governor. After installing a new governor or one that has been overhauled, adjust the governor compensating needle valve even though it has previously been done at the factory or repair facility. This adjustment must be made with the governor installed and controlling an engine with a load. If this is not done, high overspeeds and low underspeeds after load changes will result and the return to normal speeds will be slowed. Maintenance and repair of each unit must be in accordance with the manufacturer's maintenance manual and the PMS.

NOTE: When governor troubles are suspected, before performing any maintenance or adjustments, always disconnect the governor fuel rod end from the fuel control rack and ensure that there is no sticking or binding of the rack. This procedure is necessary to determine if the trouble is actually in the governor.

The chart in table 3-1 lists some of the probable causes of trouble which are common to most hydraulic governors. This chart should be used for training purposes only; it must NOT be used to troubleshoot a governor. Always use the applicable manufacturer's instruction manual for troubleshooting. Following are the definitions of the terms used in the chart.

HUNT: A rhythmic variation of speed which can be eliminated by blocking the fuel linkage manually, but which will reappear when returned to governor control.

SURGE: A rhythmic variation of speed always of large magnitude which can be eliminated by blocking the fuel linkage and which will not reappear when returned to governor control unless the speed adjustment of the load changes.

JIGGLE: A high frequency vibration of the governor fuel rod end or engine linkage. Do not confuse jiggle with normal regulating action of the governor.

Mechanical Governors

Mechanical governors used in the Navy are generally of the spring-loaded flyball type. All mechanical governors have a speed droop. This means that as the load is increased at a constant throttle setting, the speed of the engine will drop or droop slightly, rather than remain constant. Consequently, mechanical governors are never used where absolute constant speeds are necessary.

There are several types of mechanical governors. Two of the most common types are used on GM 71 engines. One type, known as the constant-speed governor, is used on generator sets and is designed to hold the speed of the engine at a predetermined operating speed. The other type is similar in construction and is used primarily for propulsion engines. It has a throttle plate so designed that speeds intermediate between idling and full speeds may be obtained by manual adjustment. The following description applies to both types of governors. Do note, however, that on the constant-speed governor, there is no buffer spring adjustment.

In the idling speed range, control is effected by centrifugal force of two sets of flyweights (figure 3-15), large and small, acting against a light

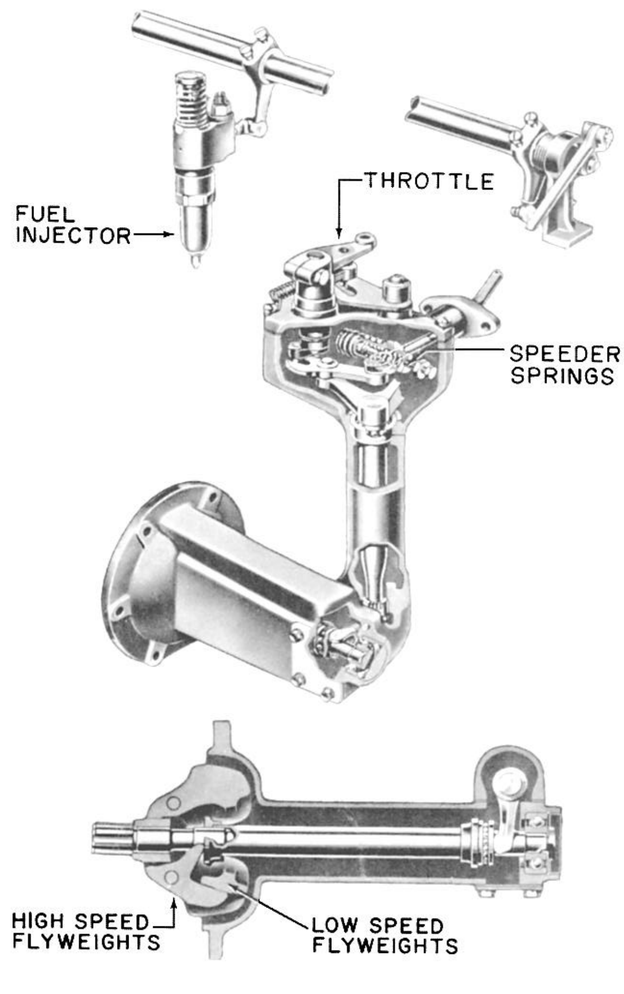

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Figure 3-15.—GM mechanical governor.

(low speed) spring. Maximum speed control is effected by the action of the high speed (small) flyweights acting against a heavy (high speed) spring. (See figure 3-16.)

Mechanical governor faults usually manifest themselves in speed variations; however, not all speed variations indicate governor faults. When improper speed variations appear do the following:

1. Check the load to be sure that speed changes are not the result of load fluctuations.

2. If the load is found to be steady, check the engine to be sure all cylinders are firing properly.

3. Make sure there is no binding in the governor mechanism or operating linkage between governor and engine, and that no binding exists in the injector control rack shaft or its mounting brackets. If you find no binding anywhere and the governor still fails to control the engine properly, you may assume the governor is worn or unfit for further service until the unit has been completely disassembled, inspected, and rebuilt or replaced.

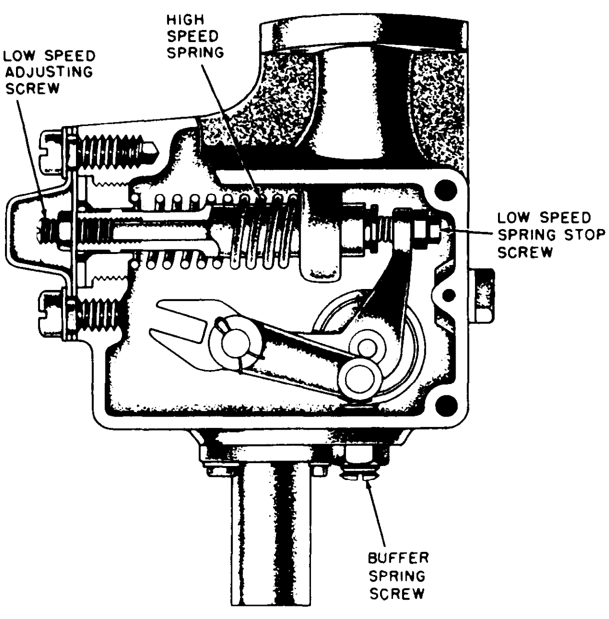

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Figure 3-16.—Mechanical governor control mechanism.

Adjustment procedures for the replacement of any governor are listed in the manufacturer's instruction manual and should be followed with particular attention given to the precautions listed.

OVERSPEED SAFETY DEVICES

Mechanical overspeed trips depend on the centrifugal forces developed by the engine and should be maintained in good working condition. A faulty overspeed device can endanger not only the engine but also personnel if the engine explodes or flies apart because of uncontrolled speed.

The engine instruction manual contains information as to the speed at which the overspeed is supposed to function. Most overspeed trips are adjustable. Prior to making any change in the adjustment of the overspeed trip, determine if the engine did not trip out for some reason other than the action of the element of the overspeed trip. It is highly advisable that you first check the accuracy of the tachometer and then test the overspeed trip. All spring tension adjustments and linkage adjustments to an overspeed trip are critical. Instructions given for making these adjustments are found in the manufacturer's instructions manual and must be followed.

Hydraulic overspeed trips are extremely sensitive to dirt. Dirt or lacquer-like deposits may cause a trip to bind internally. The speed sensitive element must be kept clean and so should all parts of the linkage and mechanisms incorporated in this speed sensitive element. When painting around the engine, the painter should be cautioned against allowing paint to fall on joints, springs, pins, and other critical points in the linkage.

All linkage binding should be eliminated. If parts are bent, badly worn, improperly installed, dirty, or if their motion is restricted by some other part of the engine, the trip will not function properly. On occasion the drive shaft of the overspeed trip may be broken and prevent rotation of the flyweight and the overspeed trip. Insufficient oil in the hydraulic trip may be another source of this problem. Oil should be maintained at the level specified in the instruction manual.

The cause of any malfunction should be determined and eliminated. This will involve cleaning the trip and its linkage, removing the source of binding, replacing faulty parts, adding oil to hydraulic type trips, or adjusting the speed sensitive element, always in accordance with the instruction manual. If the trip has been damaged, it is advisable to install a spare overspeed trip and completely rebuild or overhaul the damaged one.

REPAIR OF INTERNAL COMBUSTION ENGINES

The Navy uses so many models of diesel engines that it is not possible to describe in any detail all the overhaul procedures used by the Navy. Detailed repair procedures are listed in the manufacturers' technical manuals and in your PMS. Always consult the manuals and the maintenance requirement cards (MRCs) before starting any type of repair work. Pay particular attention to installation tolerances, wear limits, adjustments, and safety procedures. Also be sure to follow the general rules, listed below, which apply to all engines.

1. Observe the highest degree of cleanliness in handling engine parts. Engines have been completely wrecked by the presence of abrasives and various objects which have been carelessly left in the engines after overhaul. Make sure that any engine assembled for post-repair running is scrupulously free of foreign matter prior to running. Too much emphasis cannot be given to the necessity for maintaining engines clean both internally and externally. Since dirt entering the engine during overhaul causes increased wear and poor operation, it is essential that all repair work be done under clean conditions. When overhaul or repair of precision parts and surfaces is required, the parts and the surface should be thoroughly cleaned and wrapped in a clean cloth or suitable paper. The parts should then be stored in a dry place until reinstalled. During installation, parts should be wiped with a cloth free of lint and coated, where applicable, with clean lubricating oil. When removing or installing parts such as pistons, connecting rods, camshafts, and cylinder liners, make sure that these parts are not nicked or distorted. Take precautions to keep dirt and other foreign material in the surrounding atmosphere from entering the engine while it is being overhauled. As an example, during shipyard overhaul periods the engine should be protected when sandblasting is occurring in areas adjacent to the ship.

2. Before starting repair work, make sure that all required tools and spare parts are available. Plan ahead for repair periods so everything needed is available to ensure successful and expeditious completion of the work.

WARNING

Never attempt to jack the engine over by hand without first disabling the starter circuit.

3. Disable the starter circuit and tagout the starter before you start working, particularly when the jacking gear is to be engaged.

4. Keep detailed records of repairs, including measurements of worn parts (with hours in use), and the new parts installed. Later, an analysis of these records will indicate the number of hours of operation that may be expected from the various parts and will facilitate prediction as to when they should be renewed before a failure occurs. Measurement of new parts are needed to determine whether or not they come within the tolerances listed in the manufacturers' instruction books or the wear limit charts. In addition, before installation, all replacement parts should be compared with removed parts to ensure that they are suitable.

5. Do not test an overhauled diesel engine at 125% of full load or any other overload before the engine is returned to service. It has been reported that some overhauled diesel engines used for driving generators are being tested at 125% of full load before being returned to service. The original purpose for this test was to demonstrate a 25% overload capability for a 2-hour period to absorb occasional electrical peak loads. The nameplate rating of many of the older generator sets indicates a 25% temporary overload capacity. (More recent generator sets have a single rating with no stated overload requirement.) The earlier practice was a reasonable approach since the engine was frequently capable of substantially greater power than could be absorbed by the generator and the 125% test was not likely to be detrimental to the engine. Now that these engines have aged, the margin of excess power available

is less and the overload test is neither required nor desirable.

Another important point to remember is that if you cannot overhaul an engine due to lack of space, manpower, or expertise, you may request outside help by using an OPNAV Form 4790.2K. This form, when used as a work request, will be sent to a Ship Intermediate Maintenance Activity (SIMA). The SIMA will then accept or reject the work request. If the work request is accepted, the SIMA will order all repair parts, overhaul the engine, and perform an operational test in accordance with manufacturers' technical manuals and *NAVSHIPS Technical Manual,* chapter 233.

As stated earlier in this section, since maintenance cards, manufacturers' maintenance manuals, and various other instructions discuss repair procedures in detail, this chapter will be limited to general information on some of the troubles encountered during overhaul, the causes of such troubles, and the methods of repair.

PISTON ASSEMBLIES AND RODS

Piston assemblies may have the trunk-type or the crosshead-type pistons. The majority of engines in use by the Navy have trunk-type pistons. Since the troubles encountered with crosshead pistons are very similar to those encountered with the trunk type, only the latter is discussed here.

PISTONS

Trunk-type pistons are subject to such forces as gas pressure, side thrust, inertia, and friction. These forces, together with overheating and the presence of foreign matter, may cause such troubles as piston wear, cracks, piston seizure, and piston pin bushing wear (see figure 3-17).

Piston wear is characterized by an excessive clearance between the piston and the cylinder. Symptoms of excessive clearance between a piston and cylinder are piston slap and excessive oil consumption. Piston slap occurs just after top dead center and bottom dead center, as the piston shifts its thrust from one side to the other. As the cylinder taper increases with wear, oil consumption increases. Since taper causes the rings to flex on each stroke of the piston, excessive ring wear

Troubles	Possible Causes
Undue piston wear; crown and land dragging	Insufficient lubrication Improper cooling water temperatures Overload Unbalanced load Improper fit Dirty intake air cleaner Dirty oil Improper starting procedures
Cracks Crown	Faulty cooling Loose piston Obstruction in cylinder Faulty nozzle spray
Lands	Insufficient lubrication Cocked piston Insufficient ring groove clearance Excessive wear of piston ring grooves Broken ring Improper installation or removal
Piston seizure	Inadequate lubrication Excessive temperatures Improper cleaning
Piston pin bushing wear	Insufficient lubrication Excessive temperatures Overload Unbalanced load

121.1

Figure 3-17.-Piston troubles and their causes.

occurs, allowing lubricating oil to pass and be burned in the cylinder. This results in the accumulation of excessive carbon deposits on the piston, the combustion chamber, and the engine exhaust valves or ports. This accumulation of carbon deposits will cause erratic operation and greatly reduce engine efficiency.

Occasionally pistons and liners become sufficiently worn to permit the piston to cock over in the cylinder. This allows the crown and ring lands to drag on the cylinder wall. The results of dragging can be determined by visually inspecting the parts of the piston in question. However, most of the pistons now in use in the Navy are free from this trouble, since the crown and ring lands are of smaller diameter than the skirt and do not contact the cylinder wall.

Some piston wear is normal in any engine; the amount and rate depends on several controllable factors. The causes of excessive piston wear are also the causes of other piston troubles.

One of the factors controlling wear is lubrication. An adequate supply of oil is essential to provide the film necessary to cushion the piston and other parts within the cylinder and prevent metal-to-metal contact. Inadequate lubrication will not only cause piston wear but the extra friction may also cause piston seizure, land breakage, and piston pin bushing wear.

Lack of lubrication is caused either by a lack of lube oil pressure or by restricted oil passages. The pressure-recording instruments usually give warning of low oil pressure before any great harm occurs. However, clogged passages offer no such warnings. Only by inspecting and cleaning the piston and connecting rod assembly may you insure adequate lubrication.

Another controllable factor that may be directly or indirectly responsible for many piston troubles is improper cooling water temperatures. If an engine is operated at higher than the specified temperature limits, lubrication troubles will develop. High cylinder surface temperatures will reduce the viscosity of the oil. As the cylinder lubricant thins, it will run off the surfaces. The resulting lack of lubrication leads to excessive piston and liner wear. On the other hand, if the engine is operated at temperatures that are below those specified, viscosity will be increased, and the oil will not readily reach the parts requiring lubrication.

Oil plays an important part in the cooling of the piston crown. If the oil flow to the underside of the crown is restricted, deposits caused by oxidation of the oil will accumulate and lower the rate of heat transfer. For this reason, the underside of each piston crown should be thoroughly cleaned whenever pistons are removed.

While insufficient lubrication and uneven cooling may cause ring land failure, excessive oil temperatures may cause piston seizure. An increase in the rate of oxidation of the oil may result in clogged oil passages or damage to piston pin bushings.

Seizure and excessive wear of pistons may be caused by improper fit. New pistons or liners must be installed with the piston-to-cylinder clearances specified in the manufacturer’s technical manual. If clearance is insufficient, a piston will NOT wear in and will probably bind. The resulting excess surface temperatures may lead to seizure or breakage.

Binding increases wear and shortens piston life by scuffing the liner or galling the piston skirt. Scuffing roughens the liner so that an abrasive action takes place on the piston skirt, thus generating additional heat which may distort or crack the piston or liner. Galling, especially on aluminum pistons, causes the metal to be wiped in such a manner that the rings bind in the grooves.

A loose fitting piston may be just as destructive as one which is too tight. A loose piston may cause dragging and cocking of the piston, which in turn may cause broken or cracked ring groove lands.

Excessive wear on the piston and piston pin bushing may be caused by either an overload or by an unbalanced load. Overloading an engine increases the forces on the pistons and subjects them to higher temperatures, thus increasing their rate of wear. There should be a load balance on all pistons at all times. Balance of an engine is determined by checking the exhaust gas temperature at each cylinder, the rack settings, and the firing and compression pressures.

Cracking of the lands of a piston is caused by insufficient ring groove clearance. For correct piston ring operation, proper clearance must be maintained between the ring and the land, and also between the ends of the ring. This is necessary in order that the ring may be free to flex at all temperatures of operation. The clearance depends upon the ring and the materials involved.

After installing a ring, check the clearance between the ring and the land. This check is made

Excessive Wear	Sticking	Breakage
A. Symptoms: 1. Low compression 2. Hard starting 3. Loss of power 4. Smoky exhaust 5. Waste of fuel 6. Excess oil consumption 7. Poor engine operation (Other factors which may cause low compression pressure: a. Leaking cylinder valves b. Faulty injector gasket c. Faulty head gasket d. Leaking after-chamber valves e. Clogged intake ports f. Intake air header leakage g. Faulty blower h. Clogged air filter) Other factors which may cause excessive oil consumption: a. Loose bearings b. High lube oil temperatures c. Oil line leakage d. Improper oil)	C. Symptoms: 1. Low compression 2. Loss of power 3. Smoky exhaust 4. Excessive oil consumption 5. Blow-by forcing fumes from crankcase	E. Symptoms: 1. Hard starting 2. Loss of power 3. Excess oil consumption 4. Possible emission of smoke from crankcase breather
B. Causes: 1. Inadequate lubrication 2. Excessive piston heat 3. Rings damaged during installation 4. Ring- to-land clearance insufficient 5. Dust or dirt in intake air 6. Dirt in lube oil or fuel 7. Rings stuck in grooves 8. Worn cylinder liners	D. Causes 1. Improper ring-to-land clearance 2. Insufficient ring pressure 3. Excessive operating temperature 4. Improper oil 5. Improper installation	F. Causes: 1. Cylinder liner ridge 2. Cylinder port damage 3. Insufficient gap clearance 4. Insufficient clearance behind ring

Figure 3-18.—Piston ring troubles, their symptoms and causes. **121.2**

with a thickness gage, and must be made completely around the piston.

Replace most damaged or excessively worn pistons. Since replacement of damaged pistons is usually necessary, shipboard repair parts should always be maintained at full allowance.

PISTON RINGS

The troubles to which piston rings are subject and their symptoms and causes are listed in figure 3-18.

All symptoms and causes shown for ring wear are either directly and indirectly related to other ring and piston troubles. In addition to symptoms and causes of piston ring troubles, there are other factors that may also be responsible either for low compression or for excessive oil consumption.

When a cylinder with a low compression pressure is located, the possibility of the cause being some factor other than excessive wear should be eliminated before the pistons rings are disassembled or replaced. Look at figure 3-18. Of the causes listed under “Other factors which may cause low compression pressure” are a, b, c, d, and there are causes that would affect the pressure in only one cylinder assembly of a multicylinder engine. Causes f, g, and h may affect a group of cylinders, or possibly all cylinders. Therefore, when symptoms indicate compression ring wear consider first other possibilities. Excessive oil consumption is generally associated with worn oil rings, but there are other factors which may cause abnormal oil usage, and these should be checked before replacement of oil rings is undertaken.

Oxidation of the lube oil leaves carbon deposits on the rings and in the grooves. It is caused by excessive operating temperatures. The carbon buildup limits movement and expansion of the rings, prevents the rings from following the cylinder contour and sealing the cylinder, and may cause sticking, excessive wear, or breakage.

Proper clearance must exist between the ring and land as well as behind the ring, since insufficient ring groove clearance can cause the rings to stick. It is not the function of the rings to support or position the piston in the cylinder bore, but if the proper clearance does not exist, the rings are likely to become loaded by inertia forces and by side thrust on the piston—forces which should be borne solely by the skirt of trunk-type pistons.

Two factors that cause improper ring clearance are:

1. Abnormal amount of carbon deposits on rings and in grooves.
2. Improper dimensions. New rings must have the proper thickness, width, diameter, and gap.

One cause of undue loads on a ring could be insufficient gap clearance. This condition would cause the ring to be forced out and into a port of a ported cylinder, and possibly result in breakage.

A bright spot found on each end of a broken ring indicates insufficient gap clearance. Sufficient gap clearance must exist at both the top and the bottom of the cylinder bore when rings are installed.

Sticking and binding of the ring may result from insufficient ring pressure. The tendency of the ring to return to its original shape pushes it against the cylinder wall, and makes the initial seal. The pressure of the combustion gases behind the rings reinforces this seal. Pressures (compression and combination) within the cylinder force the combustion rings down and cause a seal between the bottom side of the rings and the upper side of the lands; therefore, properly wearing rings will appear shiny on the outer face and bottom side. Any discoloration (usually appearing as black lines) indicates the leakage of gases past the rings. Extended use and overheating may weaken rings to the point where they do not seat properly, and the rings are then likely to bind in the grooves. A check of the free gap for a piston ring will indicate the ring’s condition with respect to sealing qualities. If the instruction manual does not give a prescribed dimension for free gap, compare the gap with that of a new ring.

Conditions which cause piston rings to stick in the grooves, wear excessively, or break are often the result of using improper lube oil. Some lube oils cause a resinous gumlike deposit to form on engine parts. Trouble of this nature can be avoided by using Navy-approved oils, or oil recommended by the manufacturer.

Probably the greatest factor affecting the wearing of piston rings is a worn cylinder liner. Therefore, when new rings are installed, surface condition, amount of taper, and out-of-roundness of the liner must all be considered. The ring is in the best position to make allowance for cylinder wear if the ring gaps are in line with the piston bosses. Gaps of adjacent rings should be staggered 180° to reduce gas leakage.

With the wearing away of material near the top of a cylinder liner, a ridge will gradually be formed. When a piston is removed, this ridge must also be removed, even though it has caused no damage to the old set of rings. The new rings will travel higher in the bore by an amount equal to the wear of the old rings, and the replacement of the connecting rod bearing inserts will also increase piston travel. As the top piston ring will strike the ridge because of this increase in travel, breakage of the ring and perhaps of the land is almost certain if the ridge is not removed.

PISTON PINS AND PIN BEARINGS

Piston pins are made of hardened steel alloy, and their surfaces are precision finished. Piston sleeve bearings or bushings are made of bronze or a similar material. These pins and pin bearings require very little service and total failure seldom occurs.

Wear, pitting, and scoring are the usual troubles encountered with piston pins and piston pin bearings.

Wear of a pin or bearing is normal, but the rate of wear can be unnecessarily increased by such factors as inadequate and improper lubrication, overloading, misalignment of parts, or failure of adjacent parts.

Every time a piston assembly is removed from an engine, the complete assembly should be checked for wear. Piston pins and bushings should be measured with a micrometer to determine if wear is excessive. Do NOT measure areas that do not make contact, such as those between the connecting rod and piston bosses, and the areas under the oil holes and grooves. The correct and limiting values for measurements may be found in the manufacturer's technical manual for the particular engine.

Excessive wear of pins, bushings, or bearings is often the result of insufficient or improper lubrication. (These parts are usually pressure lubricated.) The failure of a pressure lubricating system is usually detected before piston pins, bushings, or bearings are seriously damaged. Insufficient lubrication of these parts is usually caused by obstructions blocking the oil passages of the connecting rods. If the bushings have been installed so that the oil holes do not line up, lubrication may be restricted. Such misalignment of oil holes may also be caused by a bushing coming loose and revolving slightly out of position. Also interchanging the upper and lower connecting rod bearings ON SOME ENGINES may obstruct the flow of oil to the upper end of the rod. Always check the manufacturer's technical manual for information on interchangeability of parts.

If there is misalignment of the connecting rods, uneven loading on piston pins and bearings will result. The fact that a rod is misaligned is usually indicated by uneven wear of the piston pin and bushing and by piston skirt wear. Misalignment may be caused by improper reaming of the bushing for proper clearance.

CONNECTING RODS

Connecting rod troubles usually involve either the connecting rod bearing or the piston pin bearing. Some of these troubles, such as misalignment, defective bolts, cracks, or plugged oil passages, can be avoided by performing proper maintenance and by following instructions in the manufacturer's technical manual.

Misalignment causes binding of the piston, piston pin, and the connecting rod journal bearing. This binding is likely to result in breakage and in increased wear of the parts, leading to total failure and possible damage to the entire engine structure. Connecting rods must be checked for proper alignment before being installed in an engine, and after any derangement involving the piston, cylinder, or crankshaft.

Defective bolts are often the result of overtightening. Connecting rod bolts should be tightened by using a torque wrench, or an elongated gage to ensure that a predetermined turning force is applied to the nut. Defective threads can cause considerable trouble by allowing the connecting rod to be loosened and cause serious damage to the engine. Whenever rod bolts are removed they should be carefully inspected for stripped or damaged threads and elongation.

Cracked rods are usually the result of overstressing caused by overloading or overspeeding or because defective material was used at the time of manufacture. It is of prime importance to discover the cracks before they have developed to the point where the failure of the rod will take place. No attempts should be made to repair cracked rods. They should be replaced; serious damage may result if breakage occurs during operation.

Restricted oil passages are often the result of improper assembly of the bushing and the connecting rod bearing inserts. They may also be due to foreign matter lodging in the oil passages.

SHAFTS AND BEARINGS

The principal shafts (crankshafts and camshafts) and associated bearings (journal bearings and antifriction bearings) of an internal combustion engine are all subject to several types of trouble. Some of the troubles may be common to all of these parts; others may be related to only one part. Causes of troubles common to all parts are metal fatigue, inadequate lubrication, and operation of the engine at critical speeds.

Metal fatigue in crankshafts, camshafts, and bearings may lead to shaft breakage or bearing failure; however, you must keep in mind that metal fatigue is only one of several possible causes which may lead to such troubles.

Fatigue failure of journal bearings in internal combustion engines is usually caused by cyclic peak loads. Such failures are accelerated by improper or loose fit of the bearing shell in its housing, and by the lack of adequate priming of the lubricating oil system before the engine is started.

Severe overloading or overspeeding of an engine increases fatigue failure. Some indication of the cause of the failure may be obtained by noting which half of a bearing failed. Overloading of the engine will cause failure of the lower halves of main journal bearings, while overspeeding may cause either the upper or the lower halves to fail.

Crankshaft or camshaft failure does not occur too often. When it does occur, it may be due to metal fatigue. Shaft fatigue failure may be caused by improper manufacturing procedures, such as improper quenching or balancing, or by the presence of torsional vibration. Shaft fatigue failures generally develop over a long period of time.

The importance of lubrication cannot be overstressed. Much that has been stated previously about proper lubricants and adequate supply and pressure of lube oils is also applicable to crankshafts, camshafts, and their associated bearings. Some of the troubles which may be caused by improper lubrication are damaged cams and camshaft bearing failure, scored or out-of-round crankshaft journals, and journal bearing failure. Lubrication difficulties you should watch for are low lube oil pressure, high temperatures, and lube oil contamination by water, fuel, and foreign particles.

Operation of an engine at critical torsional speeds and in excess of the rated speed will lead to engine shaft and bearing difficulties. Each multicylinder engine has one or several critical speeds which must be avoided in order to prevent possible breakage of the crankshaft, camshaft, and gear train.

A critical speed of the first order exists when impulses due to combustion occur at the same rate as the natural rate of torsional vibration of the shaft. If the crankshaft receives an impulse from firing at every other natural vibration of the shaft, a critical speed of the second order occurs. Operation at these speeds for any length of time may cause the shaft to break. If critical speeds are not avoided, torsional vibrations may not only cause shaft breakage but may also cause severe damage to the entire gear train assembly.

In some engines, critical speeds fall within the normal operating range; the instruction manual for the specific engine will warn against engine operation for any length of time within the critical speed range. If the critical speed range falls within the normal operating range, it must be conspicuously marked upon the engine tachometer, and every effort should be made to keep the engine from operating in the range. If this is not possible, the critical speed should be passed over as fast as possible.

Overspeeding of an engine must be avoided. If the rated speed is exceeded for any extended period of time, the increase in inertia forces may cause excessive wear of the journal bearings and other engine parts, and in uneven wear of the journals.

CRANKSHAFTS

Scored crankshaft journals are caused not only by lubrication difficulties but also by journal bearing failure or improper and careless handling during overhaul.

Journal bearing failures may cause not only scoring but also broken or bent crankshafts and out-of-round journals. Journal bearing failures may be caused by several different factors and may lead to more than one trouble. The causes and the prevention of such failures are discussed in more detail later in this chapter.

Broken or bent crankshafts may be caused by the improper functioning of a torsional vibration damper. Vibration dampers are mounted on the crankshafts of some engines to reduce the torsional vibrations set up within the crankshaft and to ensure a smoother running engine. If a damper functions improperly, torsional vibrations may rupture the internal structure of the shaft.

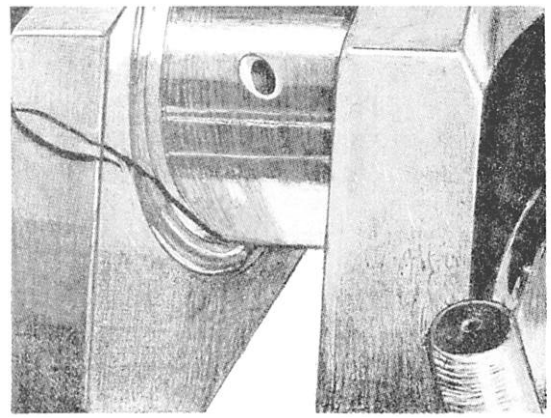
The principle of operation is similar in most dampers, yet their construction and their component parts vary somewhat. If the engine is equipped with a vibration damper, the engine instruction manual must be consulted for information on type, construction, and maintenance of the damper.

In most engines, one end of the crankshaft is flanged to receive the damper, the damper being bolted or doweled onto the flange. A damper must be fastened securely to the crankshaft at all times during engine operation; otherwise, the damper will not control the crankshaft vibrations.

Small dampers are usually grease-packed, while larger ones frequently receive lubrication from the main oil system. Dampers that are grease lubricated must have the grease changed periodically, as specified in the manufacturer's instructions. If the assembly is of the elastic type, it must be protected from fuel, lube oil, grease, and excessive heat, all of which are detrimental to the rubber.

Excessive rumbling at certain engine speeds may indicate that the damper is not functioning properly. You must learn to distinguish between this and the normal noise usually heard in some engines during the first and last few revolutions when the engine is starting or stopping. This noise is normal, it is due to the large designed clearances in the damper and is not a sign of impending trouble.

Crankshaft breakage or bending may be the result of excessive bearing clearances. Excessive clearance in one main bearing may place practically all of the load on another main bearing. Flexing of the crankshaft under load may result in fatigue and eventual fracture of the crank web. (See figure 3-19.) Excessive bearing clearance may be caused by the same factors that cause journal bearing failure. Furthermore, off-center and out-of-round journals tend to scrape off bearing material. This leads to excessive wear and to the increase of the clearance between the shaft and bearing. You can minimize the possibility of journal out-of-roundness by taking measures to prevent improper lubrication, journal bearing failure, overspeeding or overloading of the engine, excessive crankshaft deflection, and misalignment of parts.



121.3

Figure 3-19.—Cracked crank web.

Crankshaft bending breakage (out-of-roundness) may also result from excessive crankshaft deflection. Excessive shaft deflection, caused by improper alignment between the driven unit and the engine, may result in a broken or bent shaft along with considerable other damage to bearings, connecting rods, and other parts. Excessive crankshaft deflection may also be caused by overspeeding an engine. The amount of deflection of a crankshaft may be determined by the use of a straight gage.

The straight gage is merely a dial-reading inside micrometer used to measure the variation in the distance between adjacent crank webs where the engine shaft is barred over. When installing the gage, or indicator, between the webs of a crank throw, place the gage as far as possible from the axis of the crankpin. The ends of the indicator should rest in the prick-punch marks in the crank webs. If these marks are not present, you must make them so that the indicator may be placed in its correct position. Consult the manufacturer's technical manual for the proper location of new marks.

Readings are generally taken at the four crank positions: top dead center, inboard, near or at bottom dead center, and outboard. In some engines, it is possible to take readings at bottom dead center. In others, the connecting rod may interfere, making it necessary to take the reading as near as possible to bottom dead center without having the gage come in contact with the connecting rod. The manufacturer's technical manual for the specific engine provides information concerning the proper position of the crank when readings are to be taken. When the gage is in its lowest position, the dial will be upside down, necessitating the use of a mirror and flashlight to obtain a reading.

Once the indicator has been placed in position for the first deflection reading, do NOT touch the gage until all four readings have been taken and recorded.

Variations in the readings obtained at the four crank positions will indicate distortion of the crank. Distortion may be caused by several factors, such as a bent crankshaft, worn bearings, or improper engine alignment. The maximum allowable deflection can be obtained from the manufacturer's technical manual. If the deflection exceeds the specified limit, take steps to determine the cause of the distortion and to correct the trouble.

Deflection readings are also employed to determine correct alignment between the engine and the generator, or between the engine and the coupling. When alignment is being determined, a set of deflection readings is usually taken at the crank nearest to the generator or the coupling. In aligning an engine and generator, it may be necessary to install new chocks between the generator and its base to bring the deflection within the allowable value. It may also be necessary to shift the generator horizontally to obtain proper alignment. When an engine and a coupling are to be aligned, the coupling must first be correctly aligned with the drive shaft; then, the engine must be properly aligned to the coupling, rather than the coupling aligned to the engine.

CAMSHAFTS

In addition to the camshaft and bearing troubles already mentioned, the cams of a camshaft may be damaged as a result of improper valve tappet adjustment, worn or stuck cam followers, or failure of the camshaft gear.

Cams are likely to be damaged when a loose valve tappet adjustment or a broken tappet screw causes the valve to jam against the cylinder head, and the push rods to jam against their cams. This will result in scoring or breaking of the cams and followers, as well as severe damage to the piston and the cylinder.

Valves must be timed correctly at all times, not only for the proper operation of the engine but also to prevent possible damage to the engine parts. You should inspect frequently the valve actuating linkage during operation to determine if it is operating properly. Such inspections should include taking tappet clearances and adjusting, if necessary; checking for broken, chipped, or improperly seated valve springs; inspecting push rod end fittings for proper seating; and inspecting cam follower surfaces for grooves or scoring.

JOURNAL BEARINGS

Engine journal bearing failure and their causes may vary to some degree, depending upon the type of bearing. The following discussion of the causes of bearing failure applies to most bearings—main bearings as well as crank pin bearings. The most common journal bearing failures may be due to one or to a combination of the following causes:

1. Corrosion of bearing materials caused by chemical action of oxidized lubricating oils. Oxidation of oil may be minimized by changing oil at the designated intervals, and by keeping engine temperatures within recommended limits. Bearing failures due to corrosion may be identified by very small pits covering the surfaces. In most instances, corrosion occurs over small bearings areas in which high localized pressures and temperatures exist. Since the small pits caused by corrosion are so closely spaced that they form channels, the oil film is not continuous and the load-carrying area of the bearing is reduced below the point of safe operation.

2. Surface pitting of bearings due to high localized temperatures that cause the lead to melt.

This is generally the result of very close oil clearances and the use of an oil having a viscosity higher than recommended. Early stages of the loss of lead, due to melting, will be evidenced by very small streaks of lead on the bearing surface.

3. Inadequate bond between the bearing metal and the bearing shell. A poor bond may be caused by fatigue resulting from cyclic loads, or it may be the result of defective manufacturing. A failure due to inadequate bond is shown in figure 3-20. In such failures, the bearing shell shows through the bearing surface clearly.

4. Out-of-round journals due to excessive bearing wear. As the bearings wear, excessive clearance is created; this leads to engine pounding, oil leakage from the bearing, reduced flow of oil to other bearings, and overheating, with the consequent melting of bearing material. To prevent bearing wear, the journals should be checked for out-of-roundness. Manufacturers require crank pins to be reground when the out-of-roundness exceeds a specified amount, but the amount varies with manufacturers. Always check the engine manual for this type of data.

5. Rough spots. Burrs or ridges may cause grooves in the bearings and lead to bearing failure. Removal of rough spots is done with a fine oil stone and a piece of crocus cloth. Be sure to place a clean cloth beneath the journal to catch all particles. Apply a coat of clean lubricating oil to the journal and to the bearing before a bearing is installed.

6. Misalignment of parts. Misalignment of the main bearings can be caused by a warped or bent crankshaft. Such misalignment imposes heavy loads on the main bearings because of the force that is necessary to retain correct alignment between the bearing and the journal.

A bent or misaligned connecting rod can be the cause of a ruined crank-pin bearing. Misalignment between the connecting rod bore and the piston pin bushing bore is indicated by the cracking of the bearing material at the opposite ends of the upper and lower-bearing shell. An indication of a bent connecting rod is heavy wear or scoring on the piston surface.

7. Faulty installation, due to negligence or lack of experience. The paramount factor is inattention to cleanliness. Hard particles lodge between the bearing shell and the connecting rod bore, and create an air space. This space retards the normal flow of heat and causes localized high temperatures. Such condition may be further aggravated if the bearing surface is forced out into the oil clearance spaces and creates a high spot in the bearing surface. The result of a bearing failure is illustrated in figure 3-21. Foreign particles, excessive clearance, or rough surface may cause poor contact between a bearing shell and a connecting rod. Poor contact is indicated by the formation of a gumlike deposit (sometimes referred to as lacquer or varnish) on the back of the shell.

Bearing failures may result from improper fit of the shell to the connecting rod. If the locking lip of a bearing does not fit properly into the recess of the bearing housing, distortion of the shell and failure of the bearing results.

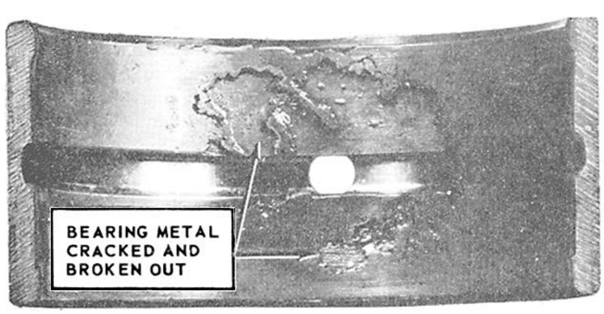


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Figure 3-20.—Bearing failure due to inadequate bond.

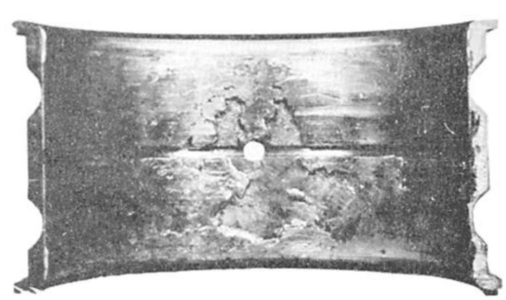

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Figure 3-21.—Bearing failure resulting from wiping and excessive temperatures.

Another source of trouble during installation is due to the interchanging of the upper and lower shells. The installation of a plain upper shell in place of a lower shell, which contains an oil groove, completely stops the oil flow and leads to early bearing failure. The resulting damage not only may ruin the bearing but may also extend to other parts, such as the crankshaft connecting rod, piston, and wrist pin.

8. Failure to follow recommended procedures in the care of lubricating oil. Lack of proper amount of lubricating oil will cause the overheating of a bearing, causing its failure (see figure 3-22). In large engines, the volume of the lubricating oil passages is so great that the time required to fill them when starting an engine could be sufficient to permit damage to the bearings. To prevent this, separately driven lubricating oil priming pumps are installed, and by their action, the oil is circulated to the bearings before an engine is started. Priming pumps should be secured prior to starting the engine when the prescribed pressure has been obtained.

Maintenance of recommended oil pressures is essential to ensure an adequate supply of oil at all bearing surfaces. Refer to the oil pressure gage as it is the best source of operational information to indicate satisfactory performance.

Use Navy-approved, low-corrosive lubricating oils at recommended oil temperatures. Recommended temperatures have been determined by extensive tests in laboratory and in service. They are sufficiently high to assure satisfactory circulation, and sufficiently low to prevent excessive oxidation of the lubricating oil. Normally, the manufacturer's technical manual should be followed as to the correct lubricating oil temperature to maintain. However, if no manual is available, the temperature of the oil leaving the engine should be maintained between 160° and 200°F. When possible, oil must be analyzed at recommended intervals to determine its suitability for further use. In addition, regular service of oil filters and strainers must be maintained, and oil samples must periodically be drawn from the lowest point in the sump to determine the presence of abrasive materials or water. The lube oil purifier should be used in accordance with required procedures. Strict adherence to recommended practices will reduce the failure of bearings and other parts because of the contaminated oil or insufficient supply of clean oil.

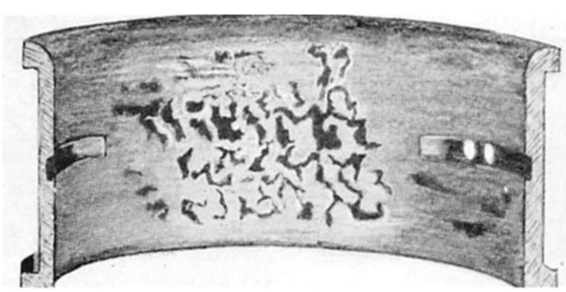

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Figure 3-22.—Overheated bearing.

FRICTIONLESS BEARINGS

Figure 3-23 lists the troubles that may be encountered with all types of (antifriction frictionless) bearings.

Since dirty bearings will have a very short service life, every possible precaution must be taken to prevent the entry of foreign matter into bearings. Dirt in a bearing which has been improperly or insufficiently cleaned may be detected by noise when the bearing is rotated, by difficulty in rotating, or by visual inspection. Do not discard an antifriction bearing until you have definitely established that something in addition to dirt has caused the trouble. You may determine this by properly cleaning the bearing.

Spalled or pitted rollers or races may be first recognized by the noisy operation of the bearing. Upon removal and after a very thorough cleaning, the bearing will still be noisy when rotated by hand. (Never spin a frictionless bearing with compressed air.) Roughness may indicate spalling at one point on the raceway.

Pay particular attention to the inner surface of the inner race, since it is here that most surface disintegration first occurs. Since pits may be covered with rust, any sign of rust on the rollers or contact surfaces of the races is a probable indication that the bearing is ruined.

Trouble	Causes
Dirty bearing	Improper handling or storage Use of dirty or improper lubricant Failure to clean housing Poor condition of seal
Spalled or pitted rollers or races	Dirt in bearing Water in bearing Improper adjustment of tapered roller bearings Bearing misaligned or off square
Dented (brinelled) races	Improper installation or removal Vibration while bearing is inoperative
Failed separator	Initial damage during installation or removal Dirt in the bearing
Races abraded on external surfaces	Locked bearing Improper fit of races
Cracked race	Improper installation or removal (cocking)
Excessive looseness	Abrasives in lubricant

Figure 3-23.—Antifriction bearing troubles and their causes.

Brinelled or dented races are most easily recognized by inspection after a thorough cleaning. Brinelling receives its name from its similarity to the Brinnell hardness test, in which a hardened ball is pressed into the material. The diameter of the indentation is used to indicate the hardness of the material. Bearing races may be brinelled by excessive and undue pressures during installation or removal, or by vibration from other machinery while the bearing is inoperative. If heavy shafts supported by frictionless bearings are allowed to stand motionless for a long time, and if the equipment is subject to considerable vibration, brinelling may occur. This is due to the peening action of the rollers or balls on the races.

Brinelled bearings must not be placed back in service. Steps can be taken to prevent brinelling. Proper maintenance will help a great deal, and the best insurance against brinelling caused by vibration is to rotate the shafts supported by the frictionless bearings at regular intervals (at least once a day) during periods of idleness. These actions will prevent the rollers from resting too long upon the same portion of the races.

Separator failure may become apparent by noisy operation. Inspection of the bearings may reveal loose rivets, failure of a spot weld, or cracking and distortion of the separator. Failure of separators can usually be avoided if proper installation and removal procedure are followed, and steps are taken to exclude the entry of dirt.

Abrasion (scoring, wiping, burnishing) on the external surface of a race indicates that relative motion has occurred between the race and the bearing housing or shaft surface. The race adjacent to the stationary member is usually made a push fit so that some creep will occur. Creep is a very gradual rotation of the race. This extremely slow rotation is desirable as it prevents repeated stressing of the same portion of the stationary race. Wear resulting from the proper creep is negligible and no damaging abrasion occurs. However, abrasion caused by locked bearings or the improper fit of the races must be prevented.

Cracked races will usually be recognized by a definite thump or clicking noise in the bearing during operation. Cleaning and inspection is the best means of determining if cracks exist. Cracks usually form parallel to the axis of the race. The cracking of bearing races seldom occurs if proper installation and removal procedures are followed.

Excessive looseness may occur on rare occasions even though no surface disintegration is apparent. Since many frictionless bearings appear to be loose, even when new, looseness is not always a sign of wear. The best check for excessive looseness is to compare the suspected bearing with a new one.

Wear of bearings, which cause looseness without apparent surface disintegration, is generally caused by the presence of fine abrasives in the lubricant. Taking steps to exclude abrasives and keeping lubricating oil filters and strainers in good condition is the best way to prevent this type of trouble.

Most of the troubles listed in figure 3-23 require the replacement of an antifriction bearing. The cause of damage must be determined and eliminated so that similar damage to the replacement bearing may be prevented.

Dirty bearings may be made serviceable with a proper cleaning, providing other damage does not exist. In some cases, races abraded on the external surfaces can be made serviceable, but it is generally advisable to replace abraded bearings. Dirty frictionless bearings must be thoroughly cleaned before being rotated or inspected.

AUXILIARY DRIVE MECHANISMS

Auxiliary drive mechanisms are used in internal combustion engines to maintain a fixed and definite relationship between the rotation of the crankshaft and the camshaft. This is necessary in order that the sequence of events necessary for the correct operation of the engine may be carried out in perfect unison. Timing and the rotation of various auxiliaries (blowers, governor, fuel and lubricating oil pumps, circulating water pumps, overspeed trips, etc.) are accomplished by a gear or chain drive mechanism from the crankshaft. (Some small engine auxiliaries may be belt-driven.)

GEAR MECHANISMS

The principal type of power transmission for timing and accessory drives in most diesel engines is a system of gears similar to those shown in figure 3-24. In some of the larger engines, there may be two separate gear trains, one for driving the camshaft and the other for driving certain accessories.

The type of gear employed for a particular drive depends upon the function it is to perform. Most gear trains use single helical spur gears, while governor drives are usually of the bevel type; reverse and reduction gear units employ double helical gears to balance fore and aft components of tooth pressure.

Small gears are usually made from a single forging, while larger ones are quite often built up in split sections. (See the crankshaft gear in figure

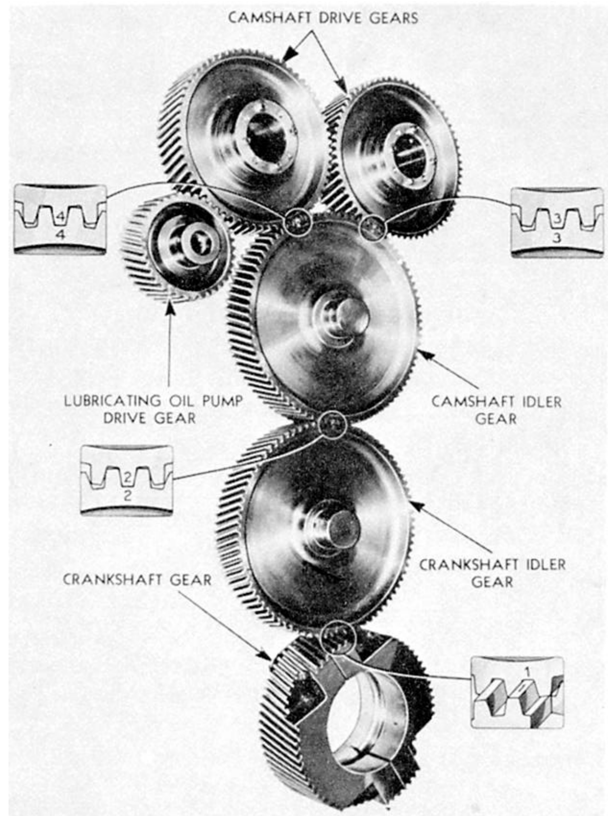

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Figure 3-24.—Relative arrangement of the gears in an auxiliary drive mechanism.

3-24.) Most gears are made of steel, although cast iron, bronze, or fiber are sometimes used.

The timing gear train shown in figure 3-24 is used on some two-stroke cycle diesel engines. The camshafts rotate at the same speed as the crankshaft. Note that two idler gears are necessary to transfer crankshaft rotation to the camshaft gears. The idler gears are used because the camshafts and crankshaft are displaced a considerable distance. If idler gears were not used, the crankshaft and camshaft gears would have to be considerably larger.

A similar timing gear train may be found in some four-stroke cycle engines, except that the camshaft gear or gears will have twice as many teeth as the crankshaft gear to permit the camshaft to rotate at one-half the crankshaft speed.

A different type of drive gear mechanism is used for a four-stroke cycle, V-type gasoline engine. The camshaft gears are driven through a train of bevel gears from the crankshaft. This arrangement serves to drive not only the camshaft but also other accessories, such as a magneto, or distributor, a fuel pump, and a tachometer. An additional gear, called the oil and freshwater pump drive gear, meshes with the crankshaft gear.

The causes of gear failure (improper lubrication, corrosion, misalignment of parts, torsional vibration, excessive backlash, wiped gear bearings and bushing, metal obstructions, and improper manufacturing procedures) are basically the same as the causes of similar troubles in other engine parts. The best method of prevention is to adhere to the prescribed maintenance procedures and follow the instructions given in the manufacturer's technical manual.

Maintenance and repair of gear trains involve a thorough check (for scoring, wearing, pitting, etc.) of the gear shafts, bushings and bearings, and gear teeth during each periodic inspection. Be sure that the oil passages are clear, and that the woodruff keys, dowel pins, and other locking devices are secured to a tight fit in order to prevent longitudinal gear movement. It is essential that all broken or chipped parts be removed from the lubrication system before new gears are installed.

An engine must not be barred over while the camshaft actuating gears are removed from the train. Should the engine be barred over, there is

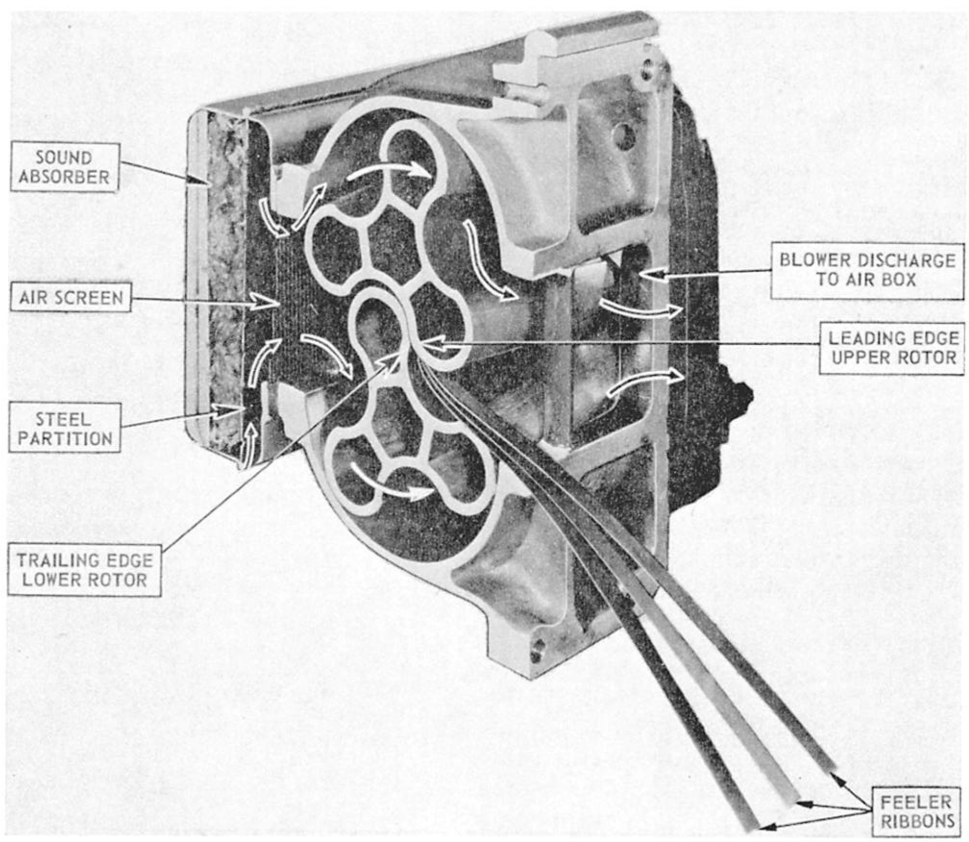

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Figure 3-25.—Checking clearance of positive displacement blower lobes.

danger that the piston will strike valves that may be open and extending into the cylinder. Make certain that any gears removed are replaced in the original position. Special punch marks, or numbers (figure 3-24), are usually found on gear teeth that should mate. If they are not present, make identifying marks to facilitate the correct mating of the gears later.

Bearing, bushing, and gear clearances must be properly maintained. If bushing clearances exceed the allowable value, the bushings must be renewed. The allowable values for backlash and bushing clearances should be obtained from the instruction manual for the engine involved.

Usually, a broken or chipped gear must be replaced. Care should be exercised in determining whether a pitted gear should be replaced.

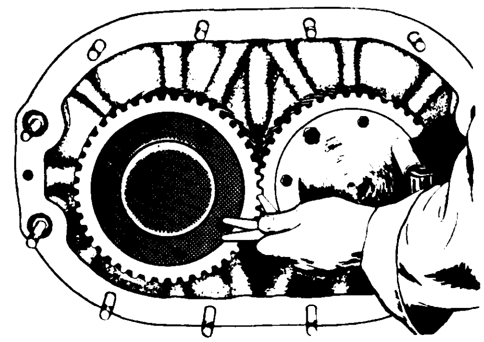
BLOWER ROTOR GEARS

One of the most important parts of a root type blower is the set of gears that drive and synchronize the two rotors. Satisfactory operation depends on the condition of these gears.

Worn gears are found by measuring the backlash of the gear set. Gears with a greater backlash than specified in the applicable technical manual are considered to be excessively worn and, if not replaced, will eventually cause extensive damage to the entire blower assembly.

A certain amount of gear wear is to be expected, but scored and otherwise damaged rotor lobes resulting from excessively worn gears are inexcusable. It is the duty of the engineering force to inspect the gears and lobes, and to measure the clearance at frequent intervals. During the inspection, it will be possible to measure accurately the values of backlash. These values should be recorded. By observing the rate of increase of wear, it will be possible to estimate the life of the gears and to determine when it will be necessary to replace them.

Lobe clearance can be found by determining the difference of the maximum and minimum rotor lobe clearance at the same distance from the center. To find the maximum clearance, hold the rotors so that there is maximum clearance between the two rotor lobes. Then, with feeler gages determine the value of the rotor lobe clearance. (See figure 3-25.)



121.9

Figure 3-26.—Checking the backlash of blower rotor gears.

The minimum clearance is found in a similar manner except that rotor lobes are held in such a position as to take up all slack and backlash. The difference of the two clearance readings is the value of the backlash of the rotor lobes. Since a change in lobe clearance is normally caused by wear of the gears, the gear clearance must be checked. The most direct method for checking gear clearance is by the use of feeler gages. (See figure 3-26.)

Any gear set which has excessive lash or shows any sign of fracture must be replaced with a new set. Since blower drive gears come in matched sets, gears from different sets must not be interchanged.

CHAIN MECHANISMS

In some engines, chains are not only used to drive camshafts and auxiliaries but also to drive such parts as rotating supercharger valves. Connecting links for two types of chains are shown in figure 3-27. Note that the connecting pins in one are secured by cotter pins, while the joint pins shown in the other are riveted.

The principal causes of drive chain failure are improper chain tension, lack of lubrication, sheared cotter pins or improperly riveted joint pins, and misalignment of parts, especially idler gears.

Chain drives should be checked for any symptoms of such difficulties, in accordance with the instructions in the appropriate engine manual. The tension should be adjusted as required during

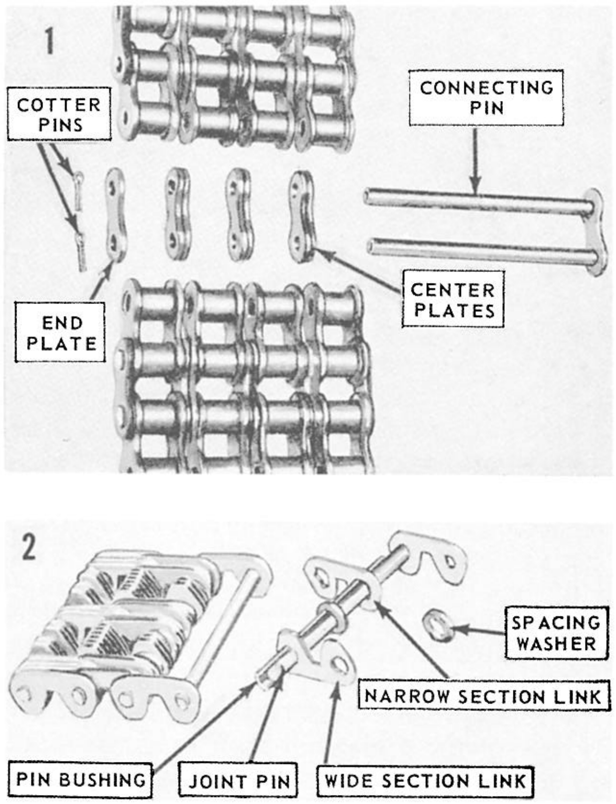


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Figure 3-27.—Accessory drive chain link assemblies.

these inspections. An idler sprocket and chain tightener are used on most engines to adjust chain tension. During operation, chains increase slightly in length because of stretch and wear. Adjustments should be made for these increases whenever necessary.

When you are installing a new chain, peen the connecting link pins into place, but avoid excessive peening. After peening, make sure the links move freely without binding in position. Cotter pins must be secured or the joint pin ends riveted, whichever is applicable. Repair links should be carried at all times. Always check engine timing after installing a new timing and accessory drive mechanism.

TURBOCHARGERS

The turbochargers used in the Navy today may operate with temperatures as high as 1200 °F and

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speeds up to 75,000 rpm. Therefore, it is of utmost importance that turbochargers be maintained in proper working order at all times. If a turbocharger is allowed to operate without lubrication, cooling, or the proper clearances, it not only could be completely destroyed in a matter of minutes but also could possibly cause extensive damage to other machinery and personnel.

All oil lines and air duct connections should be inspected and free of leakage. The air filter should be clean and in place and there should be no build-up of dust or dirt on the impeller. Turn the impeller by hand and check for binding or rubbing and listen for any unusual noises.

When the turbocharger is operating, listen for any unusual noise or vibrations. If you hear a shrill high pitch whine, shut down the engine at once. The whine may be caused by a failing bearing, and serious damage may result. Do not confuse the whine heard as the turbine runs down with that of a bad bearing.

Noise from the turbocharger may also be caused by improper clearances between the turbine wheel and the turbine housing. The clearances should be checked at predetermined intervals in accordance with the PMS. Check bearing axial end play and shaft radial movement. Crankcase vents should not be directed towards the turbocharger air intakes, as the corrosive gases may cause pitting of the blades and bearings, thereby reducing the life of the turbocharger.

CHAPTER 4

REDUCTION GEARS AND RELATED EQUIPMENT

This chapter contains information on the operation, care and maintenance of reduction gears and related equipment found on Navy ships. All EN1s and ENCs must be familiar with the design and construction details of naval reduction gears and related equipment. When more detailed information is needed, refer to the manufacturer's technical manual.

REDUCTION GEARS

The main reduction gears are the largest and most expensive single units of machinery found in the engineering department. When the main reduction gears are installed properly and are operated properly they give years of satisfactory service. However, when casualties occur to the main reduction gears they put any ship out of operation or force it to operate at reduced speed. Main reduction gear repairs are very costly. Usually they must be accomplished by a shipyard.

FACTORS AFFECTING GEAR OPERATION

Proper lubrication is essential for the efficient operation of reduction gears. This includes supplying the proper amount of oil to the gears and bearings, and keeping the oil clean and at the proper temperature. All abnormal noises and vibrations must be investigated and corrective action must be taken immediately. Gears and bearings must be inspected in accordance with current instructions issued by NAVSEA, the type commander, or other proper authority.

Lubrication of Gears and Bearings

The correct quantity and quality of lubricating oil must be available at all times in the main sump. This oil must be clean and it must be supplied to the gears and bearings at the pressure specified by the manufacturer. In order to supply the proper quantity of oil, several conditions must be met. The lubricating oil pump must deliver the proper discharge pressure, and all relief valves in the lubricating system must be set to function at their designed pressure. Too small a quantity of oil will cause the bearing to run hot. On the other hand if too much oil is delivered to the bearing, the excessive pressure will cause the oil to leak at the seal rings, and may also cause the bearing to overheat.

Lubricating oil must reach the bearing at the proper temperature. If the oil is too cold, there will be insufficient oil flow. 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 condition, should not exceed 50°F, and the final temperature of the oil leaving the gear or bearing should not exceed 180°F. Temperature rise and limit may be monitored by a thermometer or by a resistance temperature element installed where the oil is discharged from the bearings.

Cleanliness of lubricating oil cannot be overstressed. The oil must be free from such impurities as water, grit, metal, and dirt. Particular care must be taken to remove metal flakes and dirt when new gears or bearings are wearing in or after they have been opened for inspection. Lint or dirt, if left in the system, may clog the oil spray nozzles. The spray nozzle passages must be open at all times. Spray nozzles should not be altered without proper authorization.

Although the lubricating oil strainers perform satisfactorily under normal operating conditions, they 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.

EFFECTS OF WATER AND ACID IN OIL.—Water in the oil is extremely harmful. Even small amounts soon cause pitting and corrosion of the teeth. Acid can cause even more serious problems. The oil must be tested frequently for water, and periodic tests should be made for acid content. Immediate corrective measures must be taken when saltwater is found in the reduction gear lubricating oil system.

Occasionally gross contamination of the oil by saltwater occurs when a cooler leaks or when leaks develop in a sump. The immediate location and sealing of the leak is not enough. Additional steps must be taken to remove the contaminated oil from all steel parts. Several instances are known when, because such treatment was postponed—sometimes for a week or less—gears, journals, and couplings became so badly corroded and pitted that it was necessary to remove the gears and recondition the teeth and journals. Saltwater contamination of the lubricating oil may also cause bearing burnout.

Water, in small amounts, is always present within the lubrication system as a result of condensation. Air which enters the units contains moisture. This moisture condenses into water when it strikes a cooler surface and subsequently mixes with the oil. The water displaces the oil from the metal surfaces and causes rusting. Water mixed with oil also reduces the lubricating value of the oil itself.

When the main engines are secured, the oil should be circulated until the temperature of the oil and that of the reduction gear casing approximate the engineroom temperature. While the oil is being circulated, the cooler should be operated and the gear should be jacked continuously. The purifier should also be operated to renovate the oil while the oil is being circulated and after the oil circulation is stopped until water is no longer discharged from the purifier. This procedure eliminates condensation from the interior of the main reduction gear casing and reduces rusting in the upper gear case and gears.

Generally, lubricating oil will be maintained in good condition if proper use is made of the purifier and settling tanks. However, if the purifier does not operate satisfactorily and does not have the correct water seal, it will not separate the water from the oil. You can check for the presence of water by taking small samples of oil in bottles, and allowing the samples to settle. These samples should be taken from a low point in the lube oil system.

Samples of lubricating oil should be tested at every opportunity for acid, water, and sediment content at a naval shipyard (or other similar activity). With continuous use, lube oil increases in acidity, and free fatty acids form a mineral soap which reacts with the oil to form an emulsion. As the oil emulsifies, it loses its lubricating quality. Once the oil has emulsified, the removal of water and other impurities becomes increasingly difficult. When the formation of a proper oil film is rendered impossible, the oil must be renovated.

Sometimes, when a ship from the reserve fleet is placed back in commission, the rust preventive compound is not removed completely. The residue of this compound may cause serious emulsification of the lubricating oil. Operating with emulsified oil may result in damage to the bearings or the reduction gears. Since it is extremely difficult aboard ship to destroy emulsions by heating, settling, and centrifuging, you must make sure that emulsions do not occur. At the first indication of an emulsion, the plant should be stopped and the oil renovated.

MAINTAINING FOR PROPER OIL LEVEL.—It is of extreme importance that the quantity of oil in the sump be maintained within the prescribed maximum and minimum levels. Too much oil as well as too little oil in the sump can lead to trouble. If the oil level is above the prescribed maximum and the bull gear runs in the oil, the oil foams and heats as a result of the "churning" action. If the oil level is below the prescribed minimum, it may lead to a low lube oil casualty such as a damaged bearing or gears.

In gear installations where the sump tank extends'up around the bull gear, and the normal oil level is above the bottom of the gear, an oil-excluding pan (sheet metal shield) is fitted under the lower part of the gear to prevent its running in the sump oil. Under normal conditions, the bull gear comes in contact with only a small quantity of oil. The oil which tends to fill the pan is swept out by the gear and is drained back to the sump.

When there is too much oil in the sump, 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 should immediately be investigated.

Unusual Noises

A properly operating gear has a definite sound which the experienced engine operator can easily recognize. The operator should be familiar with the sounds of the gears aboard the ship during normal operation and at different speeds and under various operating conditions.

Often the readings of lube oil pressures and temperatures may help in determining the reason(s) for abnormal sounds. A burned-out pinion bearing or main thrust bearing may be indicated by a rapid rise in oil temperature for the individual bearing. A noise may indicate misalignment, improper meshing of the gear teeth, or gear tooth damage.

When there is either a burned-out bearing or trouble with the gear teeth, the main propeller shaft should immediately be stopped, locked, and inspected to determine the cause of the abnormal sound or noise. The trouble should be remedied before the reduction gear is placed back in operation.

In some cases, conditions of a minor nature may cause unusual noises in a reduction gear which is otherwise operating satisfactorily. When an investigation reveals the cause of the noise to be minor, the gear should be operated cautiously and under close observation by experienced personnel. A more thorough investigation should be made, as soon as practicable, to determine the cause of the unusual noise. Upon discovery of the trouble, appropriate action should be taken to remedy the condition.

Vibration

If the main reduction gear begins to vibrate, a complete investigation should be made, preferably by a naval shipyard. Vibrations may be caused by bent shafts, damaged propellers, misalignment between prime mover and gear, a worn out bearing, or coupling, or an improper balance in the gear train. When these units are built, the gear wheels are carefully balanced (both statically and dynamically). Later any unbalance in the gears is manifested either by unusual vibration and noise, or by unusual wear of the bearings.

When a ship has been damaged, vibration of the main reduction gear may result from misalignment of the engine and the main shafting as well as from misalignment of the engine and the main gear foundation.

When the vibration occurs within the main reduction gear, trouble or damage to the propeller should be one of the first things to consider. The vulnerable position of propellers makes them more liable to damage than any other part of the main plant. Bent or broken propeller blading and propellers fouled with line and steel cable may transmit vibration to the main reduction gear.

MAINTENANCE OF REDUCTION GEARS

Under normal conditions, all repairs and major maintenance on main reduction gears should be accomplished by a naval shipyard. However, when the services of a shipyard are not available, emergency repairs should be accomplished (where possible) either by a repair ship or at an advanced base. Minor inspections, tests, and repairs should be accomplished by the ship's force.

It is of utmost importance that the ship retain a complete record of the reduction gears from the time of commissioning. Complete installation data, furnished by the contractor, should be entered in prescribed records by the ship's engineering personnel when the ship is at the contractor's yard. They should include the crown thickness readings and the clearances of the original bearings, the thrust settings and clearances, and the backlash and root clearances for gear and pinion teeth. It is essential to have this information available at the time when the alignment must be checked.

All repairs, adjustments, readings, and casualties should be reported in accordance with 3-M system procedures. All original bearing data, as well as all additional bearing measurements, should be entered in appropriate records.

The manufacturer's technical manual, which gives detailed information regarding repairs to be made to reduction gears, is furnished to each ship.

Special tools and equipment are normally provided on board ship for (1) lifting some reduction gear covers, (2) handling the gear elements when removing or replacing their bearings, (3) making the required measurements, and (4) rebabbitting bearings.

These special tools and equipment should be available aboard ship in case repairs have to be made by repair ships or at advanced bases. Bridge gages are no longer used to check bearing wear of the main reduction gears. When bearing wear must be checked, the crown thickness method is used.

A bearing shell consists of 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 of every main reduction gear shell has three radial scribe lines on each end of the bearing shell (figure 4-1). As you can see one of these scribe lines is located at the geometric center of the shell and the remaining lines intersect the center scribe line at a 45° angle.

The crown thickness of each shell at these points should be measured with a micrometer at a prescribed distance from the end of the shell. These measurements should be recorded during the initial alignment and should be permanently marked adjacent to each scribe line.

The amount of bearing clearance should not be allowed to become too great to cause incorrect tooth contact. The designed clearances for

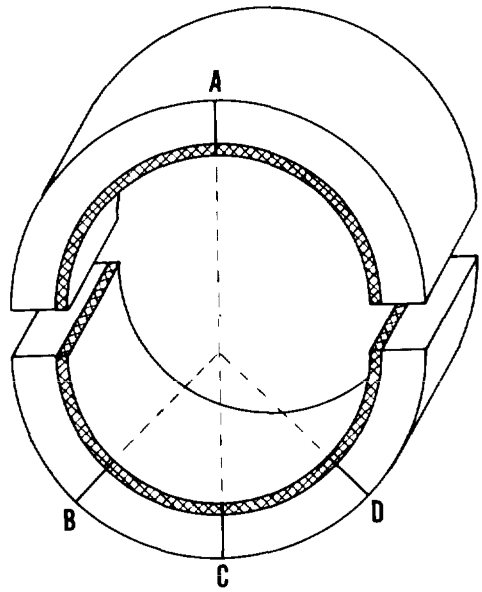

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Figure 4-1.—Scribe lines used in measuring the crown thickness of reduction gear bearings.

bearings are given in the manufacturer's technical manual. These clearances are also shown on the blueprints for the main reduction gears.

On a multishaft ship, if a main reduction gear bearing is wiped, the preferred procedure (if practicable) is to secure the shaft and the reduction gear until the units can be inspected and repaired by a repair activity.

A glance at figure 4-2 will indicate why the replacement of a bearing in a main reduction gear would be a major undertaking for the ship's force. However, emergency conditions may require action by the ship's force. When such action is to be taken, a number of factors must be taken into consideration before repairs are attempted.

The first factor to consider would be whether or not to attempt the repair work.

The EN1 or the ENC must study the manufacturer's instructions and the blueprints for the reduction gear, so as to have a clear understanding of the constructions details and the repair procedures and to be able to decide whether or not the work should be done by the ship's force. Other factors which must be considered are the location

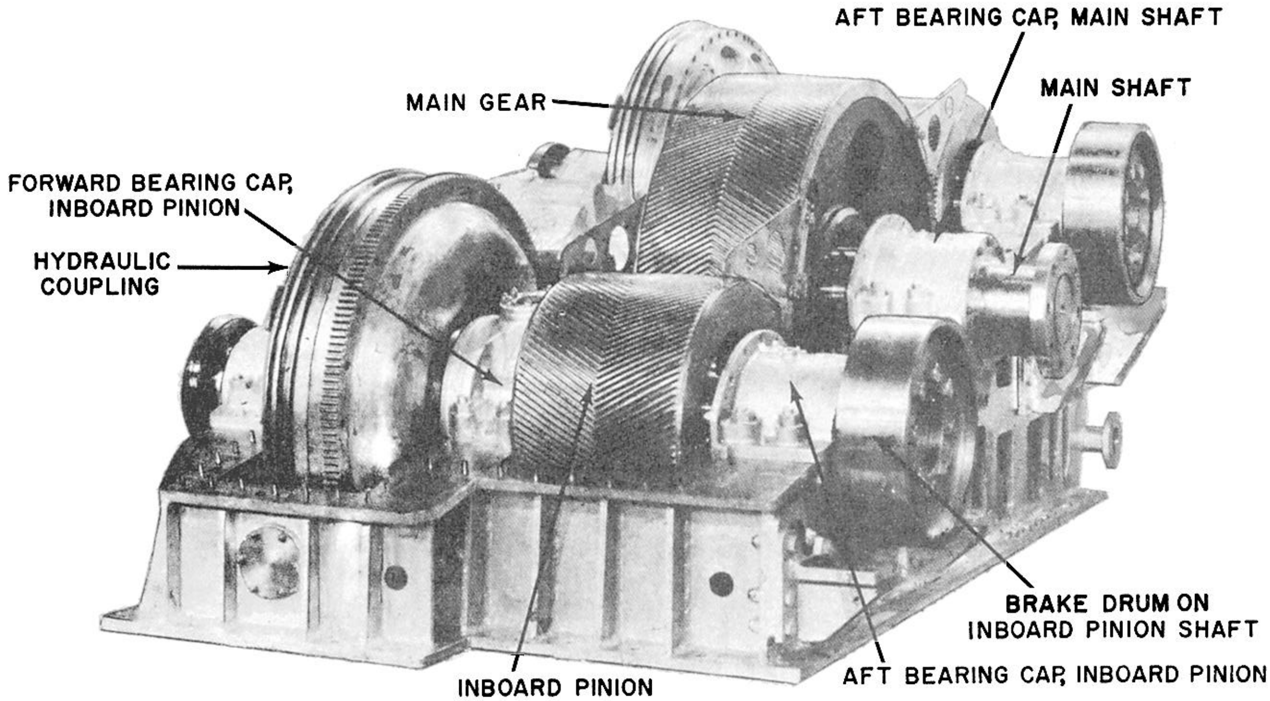

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Figure 4-2.—Starboard gear unit with cover removed—view from aft and inboard.

of the ship, the availability of Navy repair activities, and the operational schedule of the ship.

CAUTION: No portion of the gear casing or its access openings, plugs, piping, or attached fixtures shall be dismantled or removed without the specific authorization of the ship's engineer officer.

Refer to the gear shown in figure 4-2 during the following discussion. Assume that the after bearing for the inboard pinion has been wiped because of an obstructed oil passageway.

When making repairs to this unit, ensure the propeller shaft is locked rigid and the lubricating oil is pumped from the sump BEFORE the bearing cap is disturbed. For the physical security of main reduction gears refer to Naval Ship's Technical Manual chapter 9420 and current ships instructions. After removing the bearing cap, remove and inspect the upper half of the bearing. Then, with the aid of a special jack, roll out the lower half of the bearing. The function of the jack is to relieve the weight from the lower half of the bearing and to properly support the rotating elements when the journal bearings are removed.

The journal surface of the shaft and all oil passages (nozzles) should be carefully inspected and cleaned. The new bearing to be used to replace the wiped one should also be cleaned and inspected. Its crown thickness, as measured at the factory, is stamped on the new bearing. The measurements of the new bearing should be compared with those of the original bearing and with the specifications in the manufacturer's instructions.

After ensuring that the new bearing is well oiled, the lower half of the bearing can be rolled into place and the jack removed. Then the upper half is placed in position. Be sure that the bearing and its dowel are in the required position, and in accordance with the manufacturer's instructions. Afterwards, the bearing cap can be lowered into position and securely bolted down.

It is possible that the forward bearing for the inboard pinion is also damaged as a result of excessive wear. When one pinion bearing fails, that end of the shaft will tend to move away from the bull gear; consequently, an abnormal load will be placed on the other pinion bearing. For this reason, the other pinion bearing should also be opened and inspected, and checked with a micrometer, using the crown thickness method. All readings should compare with the readings listed in the manufacturer's instructions. If excessive wear is indicated, the bearing should be replaced with a new one. If no wear of the opposite pinion bearing is indicated, then the forward bearing can be reassembled.

The condition of the bearings depends a great deal upon the type of casualty that has occurred. When the casualty is due to a loss of lubricating oil, the pinion bearings must be checked first. If these bearings are in good condition, it may be assumed that the bull gear shaft bearings are also in satisfactory condition. However, after a bearing casualty has been corrected, a close watch should be maintained on all bearings.

Remember that when the reduction gear is opened, every precaution should be taken to keep out dirt and foreign matter and that the repair personnel should remove all loose articles from their clothing. Again, before closing the reduction gear, a careful inspection should be made to see that the inside of the gear is free of all dirt, foreign matter, and misplaced tools.

Gear Teeth

New gears or gears which have been realigned should be given a wearing-in run at low power before being subjected to the maximum tooth pressure of full power.

For the proper operation of the gears, it is essential that the tooth contact (or total tooth pressure) be uniformly distributed over the total area of the tooth faces. This is accomplished by accurate alignment and adherence to designed clearances. Gear tooth contact is verified by the application of Dkem to the gear teeth and by jacking the gears. Then the gears are inspected to check for the Dkem impressions.

The designed center-to-center distance of the axes of the rotating elements should be maintained as accurate as practicable. In all cases the axes of pinions and gear shafts must be parallel. Nonparallel shafts concentrate the load in one end of a helix. This situation may cause flaking, galling, pitting, featheredge on teeth, deformation of tooth contour, or breakage of tooth ends.

The designed TOOTH CONTOUR must also be maintained. If the contour is destroyed, a rubbing contact will occur with consequent danger of abrasion.

If proper tooth contact is obtained when the gears are installed, there will not be much trouble as far as the WEAR OF TEETH is concerned. Excessive wear cannot take place unless there is metallic contact, and metallic contact will not occur if adequate lubrication is provided. An adequate supply of lubricating oil at all times, proper cleanliness, and inspection for scores will prevent the wearing of teeth.

If, after all precautions have been taken, the lubricating oil supply should fail and the TEETH DO BECOME SCORED, the gears must be thoroughly overhauled by a naval shipyard, as soon as possible.

During the first few months that reduction gears are in service, PITTING may occur, particularly along the pitch line. Although slight pitting does not affect the operation of the gears, care must be taken to see that no flakes of metal are allowed to remain in the oiling system.

Play between the surfaces of the teeth in mesh on the pitch circle is known as BACKLASH. It increases as the teeth wear out. However, backlash can increase considerably without causing any trouble.

ROOT CLEARANCE.—The designed root clearance with gear and pinion operating on their designed centers can be obtained from the manufacturer's drawing or blueprint. The actual clearance can be found by taking leads or by inserting a long feeler gage or a wedge gage. This clearance should check with the designed clearances. When the root clearance is considerably different at the two ends, the pinion and gear shaft are not parallel. Some tolerance is permitted, provided that there is still sufficient backlash and that the teeth are not meshed so closely that lubrication is adversely affected.

ALIGNMENT OF GEAR TEETH.—When the gear and the pinion are parallel (axes of the two shafts are in the same plane and equally distant from each other), the gear train is aligned. In service the best indication of proper alignment is good tooth contact and quiet operation.

The length of tooth contact across the face of the pinions and gears is the criterion for satisfactory alignment of reduction gears. To static check the length of tooth contact, coat about 5 to 10 teeth with either Prussian blue or red lead, then roll the gears together with sufficient torque to cause contact between the meshing teeth and force the journals into the ahead reaction position in their bearings. After you determine the tooth contact, remove all the coating to prevent possible contamination of the lubricating oil. If tooth contact is to be checked under operating conditions, coat the teeth with red or blue Dyken or with copper sulphate.

SPOTTING GEAR TEETH.—All abnormal conditions which may be revealed by operational sounds or by inspections should be corrected as soon as possible. Rough gear teeth surfaces, resulting from the passage of foreign objects through the teeth, should be stoned smooth. If the deterioration of a tooth surface cannot be traced directly to a foreign object, give special attention to lubrication and to the condition of the bearings. Also consider the possibility that a change in the supporting structure may have disturbed the parallelism of the rotors.

Spotting reduction gear teeth is done first by coating the teeth with Prussian blue and then by jacking the gear in its ahead direction of rotation. As the gear teeth come in contact with the marked pinion teeth, an impression is left on the high part of each gear tooth. Rotate the gear about 1/4 of a turn to a convenient position for stoning. Then remove all the high spots indicated by the marking with a small handstone. Normally, it will be necessary to replace the bluing on the pinion teeth repeatedly, since if the bluing is applied too heavily you may obtain false impressions on the gear teeth.

A satisfactory tooth contact is obtained when at least 80% of the axial length of the working face of each tooth is in contact and distributed over approximately 100% of the face width.

Remember that the stoning of gears is useful only to remove a local hump or deformation, not to remove deep pitting or galling.

Main Thrust Bearings

A ship is moved through the water by an axial thrust that is developed by the propeller and transmitted to the ship's structure. This axial thrust is transmitted by the shaft through a thrust bearing which is located either at the forward end or at the after end of the main reduction bull gear or in the propeller line shafting aft of the gear. Pivoted-segmental shoe bearings (Kingsbury type) utilize a wedge-shaped film of oil in their operation. The source of lubricating oil for thrust bearings depends on the location of the bearings. In some installations oil is provided by the same system which furnishes oil to the reduction gears. In other installations, a separate lubricating system is provided.

Kingsbury-type thrust bearings consist of a collar mounted on the shaft and revolving between one or more sets of babbitt-faced segmental shoes. The backs of these shoes rest against round hardened steel pivots which permit the shoes to assume a tilt and change their angle with respect to the shaft collar. Bearings in which the thrust is always exerted in the same direction are equipped with shoes on one side only, but since provision must be made in most marine applications for thrust in two directions, it is more common to find shoes on each side of the collar. The shoes are free to adjust themselves at an angle to the collar. Rotation of the shaft collar drags a film of oil into the space between the shoes and the collar, and as the oil film forms, the shoes adjust themselves to the angle most efficient for the load conditions and the oil viscosity.

Additional information on Kingsbury-type thrust bearings and other types of bearings is provided in the *NAVSHIPS Technical Manual*, chapter 243. Detailed information on allowable tolerances and procedures for taking thrust bearing readings can be obtained from the manufacturer's technical manual.

End play checking of a Kingsbury thrust bearing must always be done with the upper half of the housing solidly bolted down, otherwise the base rings may tilt and provide a false reading.

Keep a record of the end play measurements and refer to them when checking the main thrust bearing. The normal wear of a pivoted shoe-type thrust bearing is negligible even with years of use. However, when a thrust bearing is new, there may be slight settling of the leveling plates. If you notice any increase in the end play, examine the thrust shoe surfaces, and make all necessary repairs.

In most cases, the main thrust bearing cap must be removed for inspection. The opening is of such size that it will permit the withdrawal of the pair of ahead and astern thrust shoes located in line with it.

CHECKING END PLAY WHILE RUNNING THE SHAFT.—The simplest method of checking end play is to use a suitable measuring instrument on any accessible part of the propeller shaft while running the shaft slowly ahead and astern. This is normally done at the end of a run when the ship is maneuvering to approach the pier before the machinery and shaft are cold. Although the speeds should be slow to avoid adding deflections of bearing parts and housing to the actual end play, these speeds should be sufficient to overcome the rake of the shaft and to ensure that the full end play is actually taken up.

End play is measured with a dial indicator mounted on a rigid support close to any convenient coupling flange. Occasionally a shaft may have a shoulder turned on it for the sole purpose of applying a dial indicator. Make sure that the flange surface is free from paint, burrs, and rust spots. The flange surface should also be well oiled in order to prevent damage to the dial indicator.

JACKING ON THE SHAFT FLANGE.—If it is not feasible to measure the end play of a shaft while running, your next choice is to jack the shaft fore and aft at some convenient main shaft flange.

Use a dial indicator make certain that the shaft movement is free, and guard against overdoing the jacking force. The main difficulty associated with the use of the jacking methods is in finding suitable supports to ensure that no structural damage will be incurred when jacking is done against a main shaft flange coupling.

MAIN PROPULSION SHAFT BEARINGS

You will be required to watch and maintain the main propeller shaft bearings. These bearings support and hold the propulsion shafting in alignment. They are divided into two general groups: the main line shaft bearings (spring bearings), and the stern tube and strut bearings.

MAIN LINE SHAFT BEARINGS (SPRING BEARINGS)

The main line shaft bearings (spring bearings) are of the ring-oiled, babbitt-faced, spherical seat, shell type. These bearings (figure 4-3) are designed primarily to align themselves *to* support the weight of the shafting. In many of the older, low-powered ships, the bearings are not of the self-aligning type and consist only of bottom halves. The upper half of each assembly consists only of a cap or cover (not in contact with the shaft) designed to protect the shaft journal from dirt. The spring bearings of all modern naval ships, however, are provided with both upper and lower self-aligning bearing halves.

The brass oiler rings (figure 4-3) hang loosely over the shaft journal and the lower bearing half, and are slowly drag fed around by the rotation of the shaft. The upper half of the bearing is

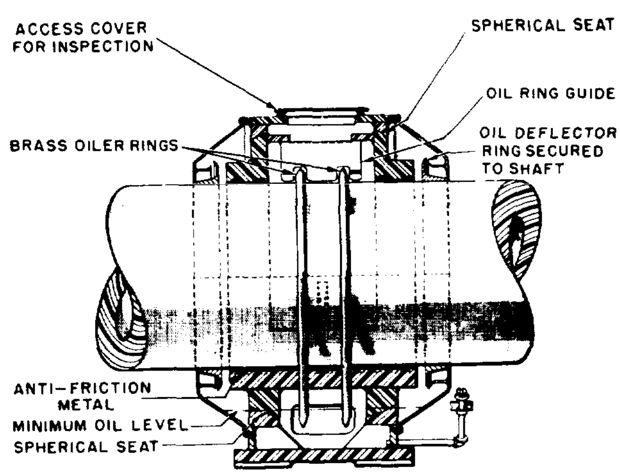

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Figure 4-3.—Main line shaft bearing.

grooved to accommodate the rings. As they glide through the reservoir of oil at the bottom, the rings carry some of the oil along to the top of the shaft journal.

On some steam driven ships, the most recent line shaft bearing design employs oiler discs instead of oiler rings for lubrication. At very low speeds (i.e., when the shaft is jacked for 24 hours while the turbines are cooling), the oil rings tend to slip and lubrication is sometimes inadequate. The oiler discs are clamped to propulsion shaft and have cavities at the periphery which carry oil to the top of the bearing regardless of the shaft speed.

Spring bearing temperatures and oil levels should be checked hourly while underway. At least once each year, the bearings should be inspected, clearances taken, and any defects corrected.

STERN TUBE AND STERN TUBE BEARINGS

The hole in the hull structure for accommodating the propeller shaft to the outside of the hull is called the stern tube. The propeller shaft is supported in the stern tube by two bearings—one at the inner end and one at the outer end of the stern tube—called stern tube bearings. At the inner end of the stern tube there is a stuffing box containing the packing gland (figure 4-4), which is generally referred to as the stern tube gland. The stern tube gland seals the area between the shaft and stern tube but allows the shaft to rotate.

The stuffing box is flanged and bolted to the stern tube. Its casing is divided into two compartments—the forward space which is the stuffing box proper, and the after space, provided with a flushing connection, designed to maintain a positive flow of water through the stern tube for lubricating, cooling, and flushing. This flushing connection is supplied by the firemain. A DRAIN CONNECTION is provided both for testing for the presence of cooling water in the bearing and for permitting sea water to flow through the stern tube and cool the bearing when underway, where natural seawater circulation is employed.

The gland for the stuffing box is divided longitudinally into two parts. The gland bolts are long enough to support the gland when the latter is withdrawn at least 1 inch clear of the stuffing

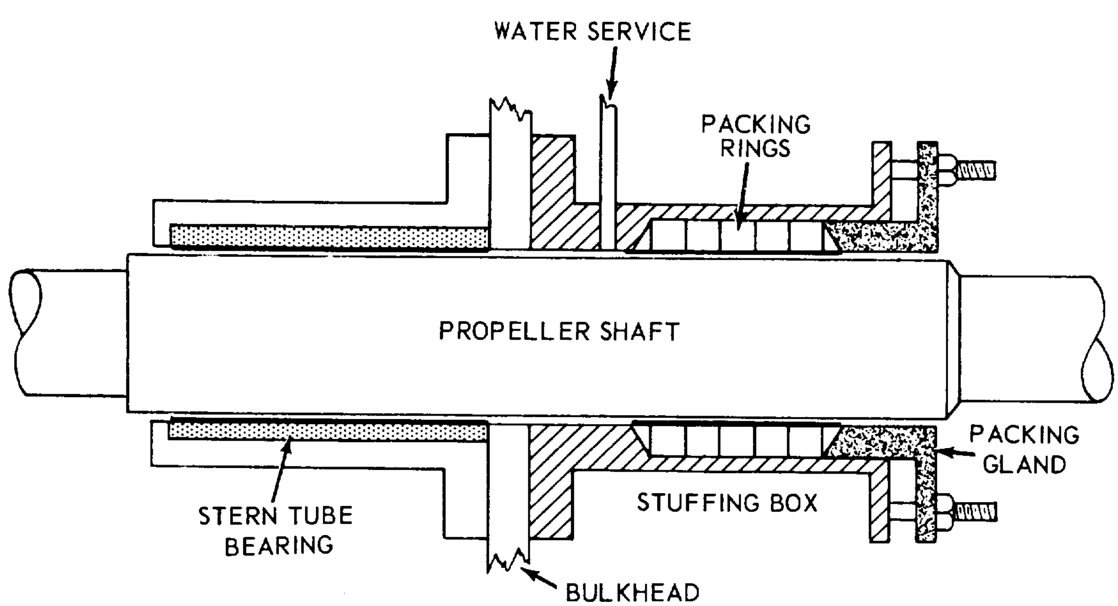

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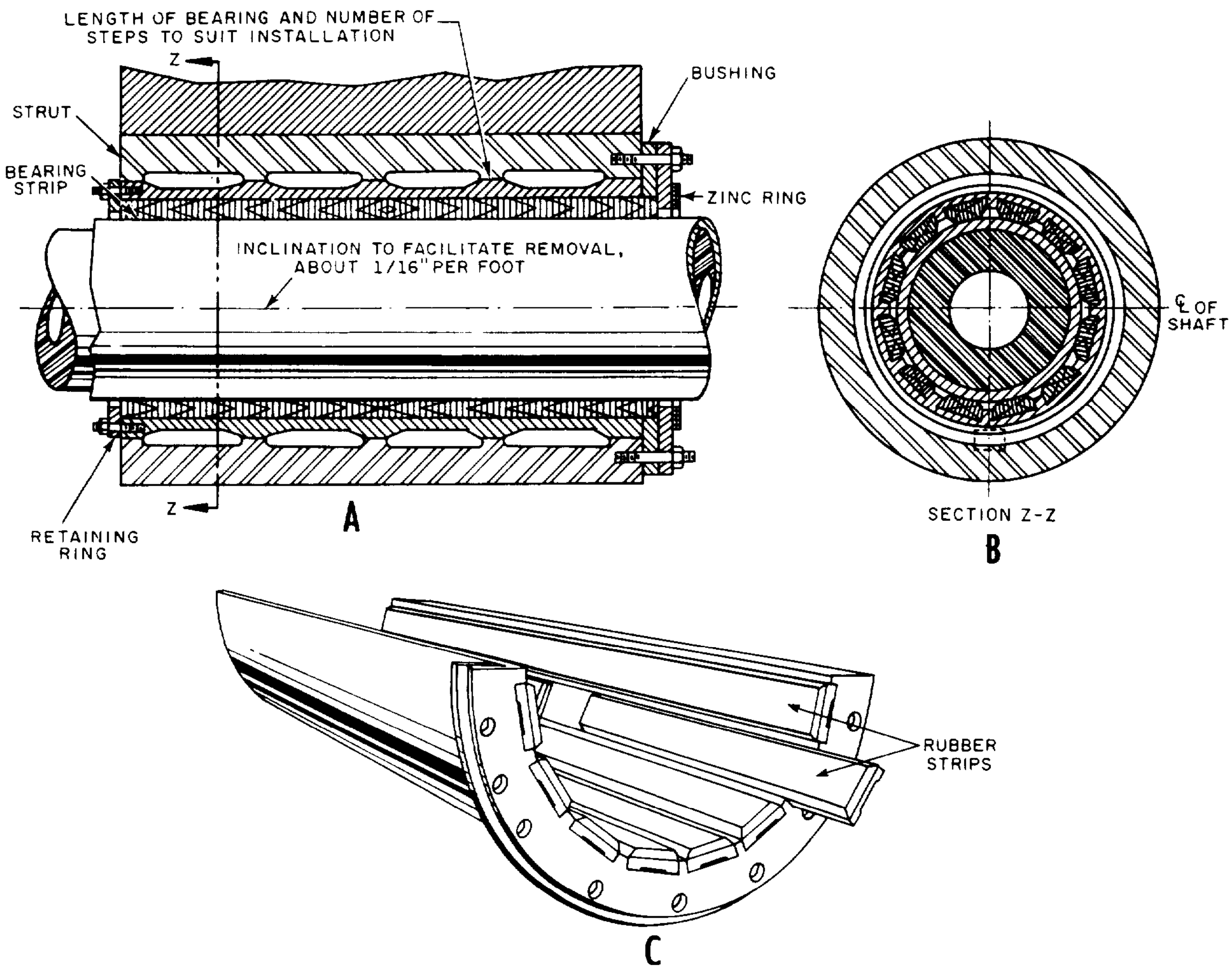
Figure 4-4.—Stern tube stuffing box and gland.



47.41

Figure 4-5.—Details of underwater strut bearing. A. Longitudinal view. B. Cross-sectional view. C. Rubber stripping in the bearing.

box. This permits the addition of a ring of new packing, when needed, while the ship is waterborne. Either braided flax packing or special semimetallic packing must be used (ship's engineering drawings show the proper type of packing). This gland is usually tightened to eliminate leakage when the ship is in port, and is loosened (prior to warming up) just enough to permit a slight trickle of water for cooling purposes when the ship is underway.

More recent shaft seal designs utilize packing only for emergencies. These newer seals are of two types; rubber face seals and mechanical face seals. Both face seals are on a plane perpendicular to the shafting, against a gland ring for rubber face seal or against a seal ring for a mechanical face seal. Further, most face seals require seawater for both cooling and lubrication.

The rubber face consists of a rubber element that is clamped around the shaft just tightly enough to prevent rotational slippage and leakage underneath the seal, while at the same time, the seal is able to travel axially along the shaft. This axial motion is necessary so that the seal can maintain its position against the gland ring regardless of shaft position.

The mechanical face seal is a ring made of either a hard synthetic or a carbon compound. This ring is held tightly against the seal ring by springs mounted behind it.

NOTE: More information on face-type seals is available in manufactures technical manuals—(Crane Co., *"Surface Ship, Seal Inc.", "Submarine").*

STRUT BEARINGS

The strut bearings, like the stern tube bearings, are equipped with composition bushings which are split longitudinally into two halves. The outer surface of the bushing is machined with steps to bear on matching landings in the bore of the strut.

Since it is usually impracticable to use oil or grease as a lubricant for underwater bearings, some other material must be employed for that purpose. Materials that become slippery when wet include natural or synthetic rubber; lignum vitae, a hard tropical wood with excellent wearing qualities; and laminated phenolic material consisting of layers of cotton fabric impregnated and bonded with phenolic resin. Strips of this material, as shown in view C of figure 4-5, are fitted inside the bearing. A rubber composition is the type most used in modern installations.

CONTROLLABLE PITCH PROPELLERS

This section will describe the major components and the principles of operation of the controllable reversible pitch (CRP) propeller (a part of the main propulsion system).

COMPONENTS OF THE CRP PROPELLER

Most ships that use CRP propellers use two independent units with their associated mechanical, hydraulic, and electronic pitch control mechanisms, plus all the required valves and seals. Some type ships require tubing and passages for the discharge of prairie air through each propeller blade. The CRP propellers form an integral part of the ship's two shaft main propulsion system. Figure 4-6 shows the major components of a single CRP propeller.

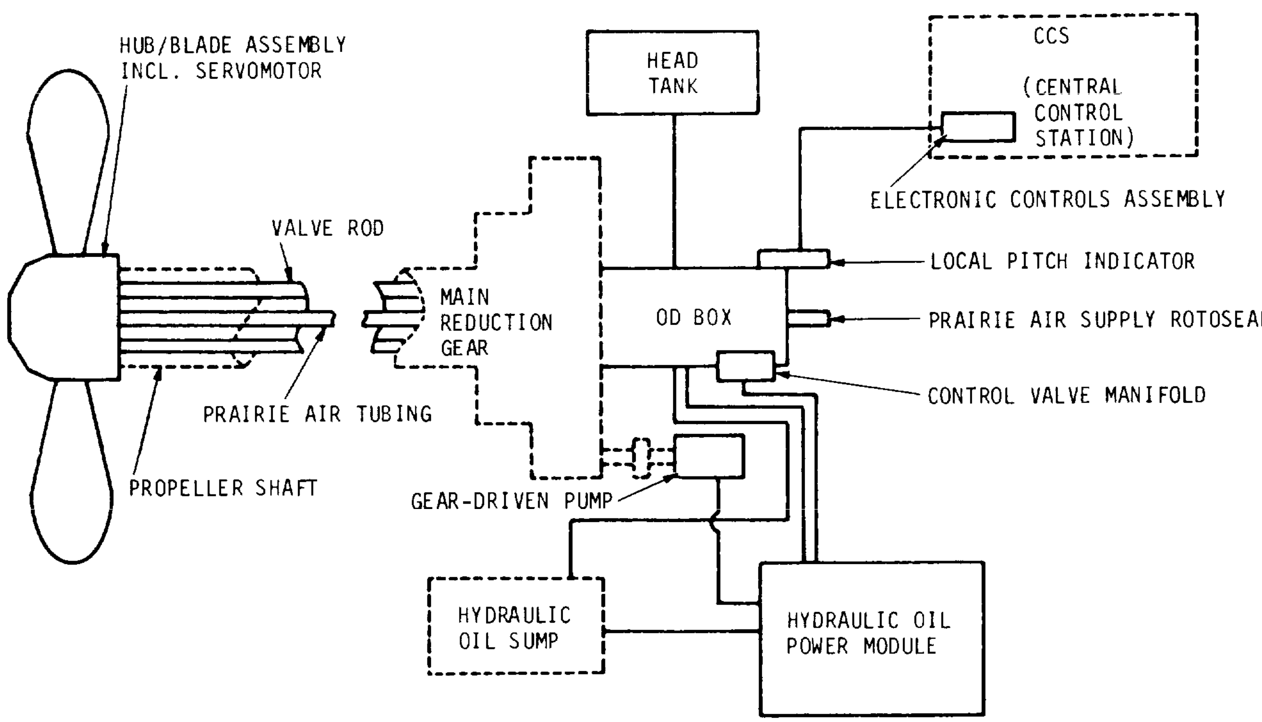


Figure 4-6.—CRP Propeller Machinery.

Table 4-1.—Related Propulstion System Components

System Name/Description
Main Reduction Gear, Mounting and Coupling for Gear-Driven Hydraulic Oil Pump.
Propeller Shaft.
Interconnecting Hydraulic Oil Piping.
Head Tank, Sump Tank and Hydraulic Oil Supply plus Associated Components, and Fittings.
Central Control Station (CCS) Controls and Indicators.

Related propulsion system components, which are necessary for the operation of a CRP propeller but which are not part of the CRP propeller are listed in table 4-1. Let's look at some of these components, along with other components, shown in table 4-2.

Hub/Blade Assembly

The propeller's hub/blade assembly (see figure 4-6), attached to the main propulsion propeller shaft, provides the mounting for the propeller blades and houses the blade turning mechanism for rotating and holding the pitch position of the blades. Attached to the after end of the hub body are the hub cone and the hub cone end cover. These items form the chamber for the servomotor piston. The hub body is fitted to the tailshaft by guide pin dowels which also transmit the torque

Table 4-2.—CRP Propeller Hardware Components

HUB BLADE ASSEMBLY Hub Assembly, LG Hub assembly. RH Blades (Set of 5). LH Blades (Set of 5). RH VALVE ROD ASSEMBLY Piping, Couplings & Guides, Port Piping, Couplings & Guides, Stbd OIL DISTRIBUTION BOX DD Box Assembly. Port DD Box Assembly, Stbd.	HYDRAULIC SYSTEM Hydraulic Oil Power Module, P/S (each including): Suction Strainer (1) Hydraulic Oil Pump, Coupling and Motor (1) Duplex Discharge Filters (3) Air Bleed Valves (2) Pressure Control Assembly, consisting of: sequence and relief valve, unloading and check valve, reducing Valve, and control oil relief valve. Manual Bypass Valve (1) Gauge Panels (2) Manifold Block Assembly, P/S (each including): Electra-hydraulic Servo Control Valve (1) Manual Pitch Control Valve (1) Manual Changeover Valves (2) Standby Hydraulic Oil Pump (gear driven), P/S Suction Strainer (gear pump), P/S Return Check Valve, P/S	ELECTRONIC PITCH CONTROL SYSTEM Electronic Pitch Control Assembly, P/S Feedback Potentiometer, P/S Readout Potentiometer, P/S LOCAL PITCH INDICATOR Pitch Indicating Assembly, P/S EMERGENCY PITCH SETTING Emergency Hand Pump Assembly, P/S PRAIRIE AIR SYSTEM Rotoseal, P/S Check Valve (hub), LH/RH Check Valve (OD Box), P/S Prairie Air Tube Assy.. P/S Connectors, Prairie Air, Hub to Blade (Set of 5). LH/RH

from the shafting to the hub assembly. The hub is secured to the tailshaft by flange bolts. These bolts are not designed to take torque from the tail shaft. The hub to tailshaft joint is sealed by O-rings located between the hub and the tailshaft, and between the tailshaft and the tailshaft spigot. Each blade is attached to a crank pin ring by blade bolts. The crank pin ring fits over and rotates about a center post which is physically a part of the hub body. The crank pin ring is retained in the hub by the bearing ring. The area under each blade is sealed by the blade port cover and by two O-rings in the blade seal base ring. Each blade seal base ring is spring-loaded against the underside of the blade port cover to provide a sealing surface under all loading conditions.

The blade turning mechanism in the hub consists of a single crosshead, attached to the end of a piston rod. Several sliding blocks are fitted into the machined chambers of the crosshead. An eccentric pin on the underside of each crank pin ring fits into a hole machined into each sliding block. The hub servomotor is attached to the after end of the crosshead. A piston rod carries the lines for the regulating valve pin which is attached to the end of the valve rod. This assembly forms a passage for hydraulic power oil flow and return oil flow to and from the hub.

Valve Rod Assembly

The valve rod assembly is composed of fabricated sections of seamless steel tubing joined by couplings to provide a mechanical link between the oil distribution (OD) box and the hub servomotor through the internal bore of the propeller shaft. The valve rod assembly provides a passage for high pressure hydraulic oil from the oil distribution box to the hub. Each valve section is supported at the center of the propeller shaft bore by guides. The after end of the valve rod assembly supports a regulating valve pin which operates in the valve pin liner of the hub servomotor. The forward end of the valve rod assembly is mechanically linked to the OD box shaft, so that the valve rod assembly turns with the shaft.

Oil Distribution Box

Presently there are two types of OD boxes being used in the Navy. One type, used on FFG-7 class and DD 963 class ships, is mounted to the forward end of the main reduction gear and is flange-connected to the main reduction gear shaft coupling. The other type, used on the LST 1179-1198 class ships, is called the Bird-Johnson Kamewa Unit; it is manufactured of steel, is cast in two sections, and is line-bored for installation over the intermediate shaft. The OD box provides a direct hydraulic oil connection to the main propulsion shaft and also translates to the valve rod in response to hydraulic control oil commands. High pressure oil from the hydraulic oil power module (HOPM) is introduced through the OD box to the internal bore of the valve rod and to the hub. The oil returns from the propeller hub to the hydraulic oil sump tank by way of the annulus between the valve rod and the internal bore of the shafting, through the OD box.

Hydraulic System

The hydraulic system consists of a self-contained HOPM, a standby hydraulic pump driven by the main reduction gear, the pitch control valves manifold block assembly, and all the associated connecting piping, fittings, and valves. The hydraulic oil is supplied to the hydraulic oil pumps from a separate sump tank. To maintain a static head pressure when the hydraulic system is shut down, a gravity head tank is connected to the OD box.

HYDRAULIC OIL POWER MODULE.—The HOPM is located adjacent to the main reduction gear. It is a RESILIENT mounted, welded structural assembly, consisting of a base plate with structural ANGLE bar, flat bar, and mounting plates. The HOPM contains the major components of the hydraulic system, including (1) either the motor-driven hydraulic screw or the vane pump, coupling, and AC motor; (2) a suction strainer for the motor-driven pump; (3) two 40 micron duplex discharge filters; (4) the pressure control assembly operating valves, which consist of a pressure reducing valve, an auxiliary relief valve, a check valve, an unloading and check valve, and a relief and sequence valve; (5) one 10 micron duplex control oil filter; (6) a gauge panel assembly and associated instrumentation; (7) a manual bypass valve; and (8) the interconnecting piping and fittings.

STANDBY PUMP.—The standby pump is of the same type as the main hydraulic pump, but it is mounted at the forward end of the main reduction gear housing and is driven through a disconnect coupling. The suction strainer and suction gauge for this pump are mounted separately. The primary function of the standby pump is to assist the main pump in effecting pitch changes. When the control pitch (C/P) unit is in the holding pitch position, the standby pump discharge oil is unloaded back to the sump through the hydraulic block. But, whenever a pitch change is ordered, the pump discharge oil is directed to the hydraulic block high pressure passage.

LOWER OIL TANK.—The lower (sump) oil tank is usually located aft and below the OD box assembly. The oil capacity of the sump varies depending on the type and class of ship. Two pumps, the main and standby hydraulic pumps, take suction on the lower oil tank through a foot valve, which permits the oil to flow from the tank but does not allow it to return through the suction line.

UPPER GRAVITY OIL TANK.—This tank is located above the maximum draft line. Its main purpose is to maintain hub oil pressure above that of the surrounding seawater when the C/P unit is secured. In the Kamewa installation, the upper gravity oil tank serves an additional purpose. During C/P unit operation the tank assists in maintaining the sliding ring chamber pressure.

PRINCIPLES OF OPERATION

The CRP propeller provides the ahead and astern propulsion thrust for a vessel by a change in the pitch of the propeller blades. Such changes can be obtained even when the main propulsion machinery, including the propeller shaft, are turning at a high rate of speed. Blade pitch control permits a full range of ahead and astern thrusts. Maximum ahead thrust is provided with the blades in the full ahead pitch position, and maximum astern thrust is provided with the blades in the full astern pitch position. When the propeller blades are set at zero thrust, the propeller shaft may be turning at any speed without imparting thrust to the vessel.

When a change of propeller pitch position is ordered, a pitch position command from the propulsion control system is fed to the controls. This command signal activates the electrohydraulic servocontrol valve which, in turn, activates the flow of control oil to and from the OD box to change the position of the valve rod actuator. The hydraulic power oil flows to the OD box and is admitted to the valve rod via the annular chamber in the OD box and the ports in the valve rod. The oil flows within the bore of the valve rod to the hub servomotor, and returns from the hub via a passage formed between the valve rod and the propulsion shaft bore. ‘The oil leaves the OD box via ports in the OD box shaft and the annular chamber to return to the sump tank. Control oil is regulated by a set of sequencing and reducing valves in the hydraulic system which maintain the required pressure level. Control oil is supplied to the electrohydraulic servocontrol valve. From the servocontrol valve, the control oil flows to one side of the low pressure (LP) chamber of the OD box to drive the valve rod actuator. Control oil returns to the sump through the OD box manifold from the other side of the LP chamber.

When the propeller is operating at the desired blade pitch position, the OD box valve rod actuator is hydraulically locked and the hub servomotor is hydraulically held in a stationary position. The configuration of the regulating valve pin in the hub servomotor allows hydraulic power oil to circulate continuously through the hub servo. The oil pressure developed on each side of the hub servomotor piston is balanced and established at the level necessary to counteract blade loading which would tend to change pitch position. A hydraulic pitch change signal from the electrohydraulic servo control valve moves the valve rod actuator and the valve rod. This movement changes the size of the oil passages to each face of the hub servomotor piston, thereby creating a differential pressure in the circulating oil to each face of the piston. The regulating valve pin then supplies high pressure oil to one face of the piston and connects the other face to the return oil passage. The high pressure oil develops the necessary pressure on the piston face to overcome blade loading and move the turning mechanism and the blades to the desired pitch position. Blade pitch will continue to change until the oil port openings equalize and the oil pressure developed on each face of the piston is balanced. Removing the oil signal from the valve rod actuator stops motion in the valve rod and the hub servomotor. The self-centering feature of the servomotor over the regulating valve pin provides the restoring force to counteract any hydrodynamic tendency to change pitch from that set by the command signal.

INSPECTIONS

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

No inspection plates or other fittings of the main reduction gear may be opened without the permission of the engineer officer. Before replacing of an inspection plate, connection, fitting, or cover which permits access to the gear casing, make a careful inspection to ensure that no foreign matter has entered or remains in the casing or oil lines. An entry of the inspections, and the name of the CPO or officer who witnesses the closing of the inspection plate, should be made in the Engineering Log.

PMS INSPECTIONS

The PMS requirements discussed in this section are general in scope. Inspection requirements for your ship are listed in the ship's PMS Manual and should be referred to for all maintenance action.

Gears should be jacked DAILY—AT ANCHOR—so that the main gear shaft is moved 1 1/4 revolutions. This jacking should be done with lubricating oil circulating in the system.

You should take the following actions QUARTERLY:

1. Sound with a hammer the holding down bolts, ties, and chocks to detect signs of loosening of casing fastenings.
2. Open inspection plates, inspect gears, and oil-spray nozzles. Wipe off oil at different points and note whether the surface is bright or if already corroded, and whether or not new areas are affected.
3. Inspect the strainers for the oil-spray nozzles to see that dirt or sediment has not accumulated in them.
4. Take and record all main thrust bearing readings.

When conditions warrant or if trouble is suspected, a work request should be submitted to a naval shipyard to perform a 7-YEAR INSPECTION of the main reduction gears. This inspection includes clearance readings of bearings and journals; alignment checks and readings; and any other inspections, tests, or maintenance work that may be considered necessary.

If the ship's propeller strikes ground or a submerged object, a careful inspection should be made of the main reduction gear immediately following the OCCURRENCE of the casualty. In this inspection, the possible misalignment of the bull gear and its shaft should be considered. Where practicable, a naval shipyard should be requested to check the alignment and concentricity of the bull gear.

NAVAL SHIPYARD OVERHAUL

During a naval shipyard overhaul, the following work should be performed: inspection of the condition and clearance of thrust shoes to ensure proper position of gear; inspection of the thrust collar, nut, and locking device; and inspection of the flexible couplings between turbines and reduction gears and removal of the sludge deposits.

FULL POWER TRIALS

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

It is not advisable to open up gear cases, bearings, and thrusts immediately BEFORE TRIALS. In addition to the inspections which may be directed by proper authority which are conducted during the FULL POWER TRIALS, the following checks must be made AFTER TRIALS. Open the inspection plates, and examine the tooth contact and the condition of the teeth to note changes that may have occurred 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 powers.) Check the clearance of the main thrust bearing.

SAFETY PRECAUTIONS

Observe the following safety precautions which apply to the operation, care, and maintenance of reduction gears and related equipment found on Navy ships.

1. If churning or emulsification of the oil in the gear case occurs, the gear must be slowed down or stopped until the defect is remedied.
2. If the supply of lubricating oil to the gears fails, the gears should be stopped and the cause located and remedied.
3. When bearings have been overheated, the gears should NOT be operated—except in extreme emergencies—until bearings have been examined and defects have been remedied.
4. If excessive flaking of metal from the gear teeth occurs, the gears should not be adjusted, except in case of emergency, until the cause has been determined.
5. Unusual noises should be investigated at once, and the gears should be operated cautiously or stopped 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 authority of the engineer officer.
7. The immediate vicinity of an inspection plate joint 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. Naked lights should be kept away from vents while gears are in use (the oil vapor may be explosive).
11. Ships anchored in localities where there are strong currents or tides should take precautions and lock the main shafts.
12. When divers are in the vicinity of the propeller, propeller shafts should be locked.
13. When a shaft is allowed to turn or trail, the lubrication system must be in operation.
14. The main propeller shaft must be brought to a dead stop position before an attempt is made to engage or disengage the turning gear.
15. When a main shaft is being locked, precautions must be taken to apply the brake quickly and securely.
16. Where there is a limiting maximum safe speed at which a ship can steam with a locked propeller shaft, this speed should not be exceeded.
17. When the main gears are being jacked over, precautions must be taken to see that the turning gear is properly lubricated.
18. Before the main engines are started, it should be definitely determined that the turning gear has been disengaged.

CHAPTER 5

ENGINE PERFORMANCE AND EFFICIENCY

Your prime concern as an Engineman is to keep the machinery for which you are responsible operating in the most efficient manner possible. From your past experience and training, you know that engine efficiency and performance depend upon much more than just operating the throttle and changing oil at prescribed intervals. The preceding chapters have covered many of the casualties which may occur to reduce the power output of an engine. You have learned how to prevent the occurrence of many of these casualties. As you gain experience and understanding, you will probably have to train other people. The people you will train will frequently come up with many questions about why an engine does or does not perform efficiently. Will you be able to answer their questions?

To understand the various factors that influence engine performance and efficiency, a thorough knowledge of the internal combustion process is necessary. Once the combustion process is understood, it will be much easier for you to appreciate the part played by such factors as engine design, engine operating conditions, fuel characteristics, fuel injection, ignition, pressures and temperatures, and compression ratios. This chapter provides some of the information necessary for a better understanding of the many factors that affect engine performance and efficiency. As an Engineman, you will be able to gain complete understanding of such factors only through continued study and practical experience.

You should know how the power which an engine can develop is limited by such factors as the mean effective pressure, the length of piston stroke, the cylinder bore, and the engine speed. You must also know how these factors are used in determining the power developed by an engine. You must learn how heat losses, efficiency of combustion, volumetric efficiency, and the proper mixing of fuel and air limit the power which a given engine cylinder can develop. You must become familiar with the factors which cause overloading of an engine and unbalance between engine cylinders. You should know the symptoms, causes, and effects of cylinder load unbalance and the steps that are necessary to maintain an equal load on each cylinder.

You must know what is meant by engine efficiency and know how the various types of efficiencies and losses are used in analyzing the internal combustion process. You must also be familiar with those factors which may cause the efficiencies to increase or decrease, and with the ways these variations affect engine performance.

Parts of this chapter may serve as a brief review, but most of the information provided deals with those factors that influence engine performance and efficiency.

ENGINE PERFORMANCE

In addition to mechanical difficulties, any engine performance may be affected by other causes, such as engine design and operator's performance. A comparison of the principal conditions which influence the performance of internal combustion engines is given in table 5-1. Note that the performance conditions for the two types of engines (diesel and gasoline) are somewhat similar, except for some differences due to factors dealing with fuel and ignition.

POWER LIMITATIONS

The design of an engine limits the amount of power that an engine can develop. Other limiting

Table 5-1.—Factors That Influence Engine Performance

	Diesel Engines	Gasoline Engines
1. Fuel characteristics	X	X
2. Compression ratio	X	X
3. Engine operating conditions		
Combustion chamber design	X	X
Valve arrangements	X	X
Size of valves	X	X
Manifold arrangements	X	X
Hot spots (presence/absence)	X	X
Location of spark plugs		X
Number of spark plugs		X
4. Pressure and temperature of air in the engine cylinder at start of compression	X	
5. Pressure/temperature of the charge in the engine cylinder at the start of compression		X

factors are the mean effective pressure, the length of stroke, the cylinder bore, and the number of revolutions per minute (piston speed) of the engine. The latter, piston speed, is limited by the frictional heat and by the inertia of the moving parts.

Mean Effective Pressure

The mean effective pressure (MEP) is the average pressure exerted on the piston during each power stroke, and is determined from a formula or by means of a planimeter. There are two kinds of mep: indicated mean effective pressure (imep), which is developed in the cylinder and can be measured; and brake mean effective pressure (bmep), which is computed from the brake horsepower (bhp) delivered by the engine.

Length of Stroke

The distance a piston travels between top and bottom dead centers (TDC, BDC) is known as the length of stroke. This distance is one of the factors that determines the piston speed. In some modern diesel engines, piston speeds may reach about 1600 feet per minute (fpm).

Cylinder Bore

Bore is used to identify the diameter of the cylinder. The cylinder bore must be known in order to compute the area of the piston crown upon which the pressure acts to create the driving force. This pressure is calculated and expressed for an area of one square inch as pounds per square inch (psi).

The ratio of length of stroke to cylinder bore is fixed in engine design; in most slow speed engines, the stroke is greater than the bore.

Revolutions Per Minute

Revolutions per minute (rpm) is the speed at which the crankshaft rotates. Since the piston is connected to the shaft, the rpm, along with the length of the stroke, determine piston speed. Since, during each revolution, the piston completes one up-stroke and one down-stroke, piston speed is obtained by multiplying the rpm by twice the length of the stroke. This speed is usually expressed in feet per minute (fpm). If the stroke is 10.5 inches (or 10.5/12 of a foot), and the speed of rotation is 720 rpm, the piston speed is computed as follows:

$$720 \times 2 \times \frac{10.5}{12} = 1260 \text{ fpm}$$

HORSEPOWER COMPUTATION

The power developed by an engine depends upon the type of engine as well as the speed of the engine. A cylinder of a single-acting, 4-stroke cycle engine will produce one power stroke for every two crankshaft revolutions, while a single-acting, 2-stroke cycle engine produces one power stroke for each revolution.

Indicated Horsepower

The power developed within a cylinder can be calculated by measuring the imep and the engine speed. (The rpm of the engine is converted to the number of power strokes per minute.) With the bore and stroke known (available in engine manufacturers' technical manuals), the horsepower (hp) can be computed. This power is called indicated horsepower (ihp) because it is obtained from the pressure measured with an engine indicator. Power loss due to friction is not considered in computing ihp.

Using the factors which influence the engine's capacity to develop power, the general or standard formula for calculating ihp is as follows:

$$\text{ihp} = \frac{P \times L \times A \times N}{33{,}000}$$

where

P = Mean indicated pressure, in psi

L = Length of stroke, in feet

A = Effective area of the piston, in square inches

N = Number of power strokes per minute

33,000 = Unit of power (one horsepower), or footpounds per minute.

To illustrate the use of this formula, assume that a 12-cylinder, 2-stroke cycle, single-acting engine has a bore of 8.5 inches and a stroke of 10 inches. Its rated speed is 744 rpm. With the engine running at full load and speed, the imep is measured and found to be 105 psi. What is the ihp developed by the engine?

In this case

$$P = 105; \quad L = \frac{10}{12};$$

$$A = 3.1416\left(\frac{8.5}{2}\right)^2; \quad N = 744$$

Substituting these amounts in the formula, you have

$$\text{ihp} = \frac{105 \times \frac{10}{12} \times 3.1416\left(\frac{8.5}{2}\right)^2 \times 744}{33{,}000} = 111.9$$

This amount represents the horsepower developed in only one cylinder; since there are 12 cylinders in this engine, total horsepower for the engine will equal 12 times 111.9, or approximately 1343.

Brake Horsepower

Brake horsepower (bhp), sometimes called shaft horsepower, is the amount of power available for useful work. Bhp is less than ihp because of the various power losses which occur during engine operation.

To determine the brake or shaft horsepower that is delivered as useful work by an engine, the sum total of all mechanical losses must be deducted from the total ihp.

CYLINDER PERFORMANCE LIMITATIONS

The factors which limit the power that a given cylinder can develop are the piston speed and the mep. The piston speed, as stated before, is limited by the inertia forces set up by the moving parts and by frictional heat. In the case of the mep, the limiting factors are as follows:

1. Heat losses and efficiency of combustion.
2. Volumetric efficiency (the amount of air charged into the cylinder and the degree of scavenging).
3. Mixing of the fuel and air.

The limiting meps, both bmep and imep, are prescribed by the manufacturer or NAVSEA. They should never be exceeded. In a direct-drive ship, the meps developed are determined by the rpm of the power shaft. In electric-drive ships, the horsepower and bmep are determined by a computation based on readings from electrical instruments and from generator efficiency.

CYLINDER LOAD BALANCE

In order to ensure a balanced, smooth-operating engine, the general mechanical condition of the engine must be properly maintained so that the power output of the individual cylinders is within the prescribed limits at all loads and speeds. In order to have a balanced load on the engine, each cylinder must produce its share of the total power developed. If the engine is developing its rated full power, or nearly so, and one cylinder or more is producing less than its share, the remainder of the cylinders will become overloaded.

Using the rated speed and bhp, it is possible to determine for each INDIVIDUAL CYLINDER a rated bmep which may not be exceeded without overloading the cylinder. If the ENGINE rpm drops below the rated speed, then the cylinder bmep generally drops to a lower value. The bmep should never exceed the normal mep at lower engine speed. Usually, it should be somewhat lower if the engine speed is decreased.

Some engine manufacturers design the fuel systems so that it is impossible to exceed the rated bmep. This is done by installing a positive stop to limit the maximum throttle or fuel control. This positive stop regulates the maximum amount of fuel that can enter the cylinder and limits the maximum load of the cylinder.

In order to meet emergency situations, engines used by the Navy are generally rated lower than those designed for industrial use. The economical speed for most of the Navy's diesel engines is approximately 90% of the rated speed. For such speed, the best load conditions have been found to be from 70% to 80% of the rated load or output. When an engine is operated at an 80-90 combination (80% of rated load at 90% rated speed) the parts last longer and the engine remains cleaner and in better operating condition.

Diesel engines do not operate well at exceedingly low bmep such as that occurring at idling speeds. You are well aware that idling an engine tends to gum up parts associated with the combustion spaces. Operating an engine at idling speeds for long periods will result in the necessity for cleaning and overhauling the engine much sooner than when operating at 50 to 100% of load.

Symptoms of Unbalance

Evidence of an unbalanced condition between the cylinders of an engine may be indicated by the following symptoms:

1. Black exhaust smoke. When this occurs, it is not always possible to determine immediately whether the entire engine or just one of the cylinders is overloaded. To determine which cylinder is overloaded, you must open the

indicator cock on each individual cylinder and check the color of the exhaust.

2. High exhaust temperatures. If the temperatures of exhaust gases from individual cylinders become higher than normal, it is an indication of an overload within the cylinder. If the temperature of the gases in the exhaust header becomes higher than usual, it is an indication that all cylinders are probably overloaded. Frequent checks on the pyrometer will indicate whether each cylinder is firing properly and carrying its share of the load. Any sudden change in the exhaust temperature of any cylinder should be investigated immediately. The difference in exhaust temperatures between any two cylinders should not exceed the limits prescribed in the engine manufacturer's technical manual.

3. High lubricating oil and cooling water temperatures. If the temperature gages for these systems show an abnormal rise in temperature, an overloaded condition may exist. The causes of the abnormal temperature in these systems should be determined and corrected immediately if engine efficiency is to be maintained.

4. Excessive heat. In general, excessive heat in any part of the engine may indicate overloading. An overheated bearing may be the result of an overloaded cylinder; or an abnormally hot crankcase may be the result of overloading the engine as a whole.

5. Excessive vibration or unusual sound. If all cylinders are not developing an equal amount of power, the forces exerted by individual pistons will be unequal. When this occurs, the unequal forces cause an uneven turning movement to be exerted on the crankshaft, and vibrations are set up. Through experience, you will learn to tell by the vibrations and sound of an engine when a poor distribution of load exists. You should use every opportunity to observe and listen to engines running under all conditions of loading and performance.

Causes of Unbalance

An engine must be kept in excellent mechanical condition to prevent unbalance. A leaky valve or fuel injector, leaky compression rings, or any other mechanical difficulties will make it impossible for you to balance the load unless you secure the engine and dismantle at least a part of it.

To obtain equal load distribution between individual cylinders, the clearances, tolerances, and the general condition of all parts that affect the cycle must be maintained so that very little, if any, variation exists between individual cylinders. Unbalance will occur unless the following conditions are as nearly alike as possible for all cylinders:

1. Compression pressures
2. Fuel injection timing
3. Quantity and quality of fuel injected
4. Firing pressures
5. Valve timing and lift

When unbalance occurs, correction usually involves repair, replacement, or adjustment of the affected part or system. Before any adjustments are made to eliminate unbalance, it must be determined beyond any doubt that the engine is in proper mechanical condition. When an engine is in good mechanical condition, few adjustments will be required. However, after an overhaul in which piston rings or cylinder liners have been renewed, considerable adjustment may be necessary. Until the rings become properly seated, some lubricating oil will leak past the rings into the combustion space. This excess oil will burn in the cylinder, giving an incorrect indication of fuel oil combustion. If the fuel pump is set for normal compression, and the rings have not seated properly, the engine will become overloaded. As the compression rises to normal pressures, there will be an increase in the power developed, as well as in the pressure and temperature under which the combustion takes place. Therefore, when an overhaul has been completed, the engine instruments must be carefully watched until the rings are seated, and all necessary adjustments are made. Frequent compression tests will serve as a helpful aid in making the necessary adjustments. Unless an engine is so equipped that compression can be readily varied, the engine should be operated under light load until the rings are properly seated.

Effect of Unbalance

From the preceding discussion, it can be readily seen that, in general, the result of unbalance will be overheating of the engine. The clearances established by the engine designer allow for sufficient expansion of the moving parts when the engine is operating at the designed temperatures, but an engine operating at temperatures in excess of those for which it was designed is subject to many casualties. Excessive expansion soon leads to seizure and burning of the engine parts. Should the temperatures in the crankcase rise above the flash point of the lubricating oil vapors, an explosion may result. High temperature may destroy the oil film between adjacent parts, and the resulting increased friction will further increase the temperature.

Since power is directly proportional to the mep developed in a cylinder, any increase in mep will cause a corresponding increase in power. If the meps in the individual cylinders vary, power will not be evenly distributed among the cylinders.

The quality of combustion obtained depends upon the heat content of the fuel. The amount of heat available for power depends upon temperature. Temperature varies directly as pressure; therefore a decrease in pressure will result in a decrease in temperature, and in poor combustion. Poor combustion will cause lowered thermal efficiency and reduced engine output.

Cylinder load balance is essential if the desired efficiency and performance of an engine is to be obtained. To avoid the harmful effects of overloading and unbalancing of load, the load on an engine should be properly distributed among the working cylinders; and no cylinder, or the engine itself, should ever be overloaded.

In general, load balance in an engine can be maintained if the following procedures are observed:

1. Maintain the engine in proper mechanical condition.
2. Adjust the fuel system according to the manufacturer's instructions.
3. Operate the engine within the temperature limits specified in appropriate instructions.
4. Keep cylinder temperatures and pressures as evenly distributed as possible.
5. Train yourself to recognize the symptoms of serious engine conditions.

ENGINE EFFICIENCY

Engine efficiency is the amount of power developed as compared to the energy input which is measured by the heating value of the fuel consumed. The term "efficiency" is used to designate the relationship between the result obtained and the effort expended to produce the result.

The term "compression ratio" is frequently used in connection with engine performance. From your study of the principles of internal combustion, you will recall that compression ratio is the ratio of the volume of air above the piston, when the piston is at the BDC position, to the volume of air above the piston when the piston is at the TDC position.

EFFICIENCIES

The principal efficiencies which must be considered in the internal combustion process are cycle, thermal, mechanical, and volumetric.

Cycle Efficiency

The efficiency of any cycle is equal to the output divided by the input. The efficiency of the diesel cycle is considerably higher than the Otto or constant volume cycle because of higher compression ratio and because combustion starts at a higher temperature. In other words, the heat input in a diesel engine is at a higher average temperature. Theoretically, a gasoline engine using the Otto cycle would be more efficient than the diesel engine if equivalent compression ratios could be used. However, engines operating on the Otto cycle cannot use a compression ratio comparable to that of diesel engines because fuel and air are drawn together into the cylinder and compressed. If comparable compression ratios were used, the fuel would fire or detonate before the piston reached the correct firing position.

Since temperature and amount of heat content which is available for power are proportional to each other, the cycle efficiency is actually computed by measuring the temperature. The specific heat of the mixture in the cylinder is either known or assumed, and when combined with the temperature, the heat can be calculated at any instant.

Thermal Efficiency

Thermal efficiency is the measure of the efficiency and completeness of combustion of the fuel, or, more specifically, the ratio of the output or work done by the working substance in the cylinder in a given time to the input or heat energy of the fuel supplied during the same time. Two kinds of thermal efficiency are generally considered for an engine: indicated thermal efficiency and overall thermal efficiency.

Since the work done by the gases in the cylinder is called indicated work, the thermal efficiency determined by its use is often called INDICATED THERMAL EFFICIENCY (ite). If all the potential heat in the fuel could be delivered as work, the thermal efficiency would be 100%. Because of the various losses, however, this percent is not possible in actual installations.

If the amount of fuel injected is known, the total heat content of the injected fuel can be determined from the heating value, or Btu per pound, of the fuel; and the thermal efficiencies for the engine can then be calculated. From the mechanical equivalent of heat (778 foot-pounds equal 1 Btu and 2545 Btu equal 1 hp-hr), the number of foot-pounds of work contained in the fuel can be computed. If the amount of fuel injected is measured over a period of time, the rate at which the heat is put into the engine can be converted into potential power. Then, if the ihp developed by the engine is calculated, as previously explained, the indicated thermal efficiency can be computed by the following expression:

$$\text{ite} = \frac{\text{hp} \times 2545 \text{ Btu per hr per hp}}{\text{Rate of heat input of fuel in Btu per hr}} \times 100$$

For example, assume that the same engine used as an example in computing ihp consumes 360 pounds (approximately 50 gallons) of fuel per hour, and that the fuel has a value of 19,200 Btu per pound. What is the ite of the engine?

The work done per hour when 1343 ihp are developed is 1343 × 2545 or 3,417,935 Btu. The heat input for the same time is 360 × 19,200 or 6,912,000 Btu. Then, by the above expression, the indicated thermal efficiency is as follows:

$$\text{ite} = \frac{1343 \times 2545}{360 \times 19{,}200} \times 100$$

$$= \frac{3{,}417{,}935}{6{,}912{,}000} \times 100 = 49.4\%$$

The other type of thermal efficiency—OVERALL THERMAL EFFICIENCY—considered for an engine is a ratio similar to ite, except that the useful or shaft work (bhp) is used. Therefore, overall efficiency (often called brake thermal efficiency) is computed by the following expression:

Overall thermal efficiency =

$$\frac{\text{bhp}}{\text{Heat input of fuel}} \times 100$$

Converting these factors into the same units (Btu), the expression is written as power output in Btu divided by fuel input in Btu.

For example, if the engine used in the preceding problem delivers 900 bhp (determined by the manufacturer) what is the overall thermal efficiency of the engine?

1 hp-hr = 2545 Btu

900 bhp × 2545 Btu per hp-hr =

2,290,500 Btu output per hr

Substituting factors already known, overall thermal efficiency is computed as follows:

Overall thermal efficiency =

$$\frac{2{,}290{,}500}{6{,}912{,}000} = 0.331, \text{ or } 33.1\%$$

Compression ratio influences the thermal efficiency of an engine. Theoretically, the thermal efficiency increases as the compression ratio is increased. The minimum value of a diesel engine compression ratio is determined by the compression required for starting; and this compression is, to a large extent, dependent on the type of fuel used. The maximum value of the compression ratio is not limited by the fuel used, but is limited by the strength of the engine parts and the allowable engine weight per bhp output.

Mechanical Efficiency

This is the rating that shows how much of the power developed by the expansion of the gases in the cylinder is actually delivered as useful power. The factor which has the greatest effect on mechanical efficiency is friction within the engine. The friction between moving parts in an engine remains practically constant throughout the engine's speed range. Therefore, the mechanical efficiency of an engine will be highest when the engine is running at the speed at which maximum bhp is developed. Since power output is bhp, and the maximum horsepower available is ihp, then

$$\text{Mechanical efficiency} = \frac{\text{bhp}}{\text{ihp}} \times 100$$

During the transmission of ihp through the piston and connecting rod to the crankshaft, the mechanical losses which occur may be due to friction, or they may be due to power absorbed. Friction losses occur because of friction in the various bearings, between piston and piston rings, and between piston rings and the cylinder walls. Power is absorbed by valve and injection mechanisms, and by various auxiliaries, such as the lubricating oil and water circulating pumps and the scavenge and supercharge blowers. As a result, the power delivered to the crankshaft and available for doing useful work (bhp) is less than indicated power.

The mechanical losses which affect the efficiency of an engine may be called frictional horsepower (fhp) or the difference between ihp and bhp. The fhp of the engine used in the preceding examples, then, would be 1343 (ihp) – 900 (bhp) = 443 fhp, or 33% of the ihp developed in the cylinders. Then, using the expression for mechanical efficiency, the percentage of power available at the shaft is computed as follows:

$$\text{Mechanical efficiency} = \frac{900}{1343} = 0.67, \text{ or } 67\%$$

When an engine is operating under part load, it has a lower mechanical efficiency than when operating at full load. The explanation for this is that most mechanical losses are almost independent of the load, and therefore, when load decreases, ihp decreases relatively less than bhp. Mechanical efficiency becomes zero when an engine operates at *no* load because then bhp = 0, but ihp is not zero. In fact, if bhp is zero and the expression for fhp is used, ihp is equal to fhp.

To show how mechanical efficiency is lower at part load, assume the engine used in preceding examples is operating at three-fourths load. Brake horsepower at three-fourths load is 900 × 0.75 or 675. Assuming that fhp does not change with load, fhp = 443. The ihp is, by expression, the sum of bhp and fhp.

$$\text{ihp} = 675 + 443 = 1118$$

Mechanical efficiency = 675/1118 = 0.60, or 60%; this is appreciably lower than the 67% indicated for the engine at full load.

Bmep is a useful concept when dealing with mechanical efficiency. Bmep can be obtained if the standard expression for computing horsepower (ihp) is applied to bhp instead of ihp and the mean pressure (p) is designated as bmep.

$$\text{bhp} = \frac{(\text{bmep}) \times L \times A \times N}{33{,}000}$$

or

$$\text{bmep} = \frac{33{,}000 \times \text{bhp}}{L \times A \times N}$$

From the relations between bmep, bhp, ihp, and mechanical efficiency, by designating indicated mean effective pressure by imep in the expression, one can also show:

bmep = imep × mechanical efficiency

To illustrate this, the bmep for the engine in preceding examples at full load and three-fourths load is computed as follows:

$$\text{bmep} = \frac{\frac{33{,}000 \times \text{bhp}}{12}}{L \times A \times N} = \frac{\frac{33{,}000 \times 900}{12}}{\frac{10 \times 56.14 \times 744}{12}}$$

$$= 70 \text{ psi}$$

or

$$\text{bmep} = \text{imep} \times \text{mechanical efficiency}$$

$$= 105 \times 67, \text{ or } 70 \text{ psi}$$

Bmep gives an indication of the load an engine carries, and what the output is for piston displacement. As the bmep for an engine increases, the engine develops greater horsepower per pound of weight. For a given engine, bmep changes in direct proportion with the load.

Volumetric Efficiency

The volumetric efficiency of a 4-stroke engine is the relationship between the quantity of intake air and the piston displacement. In other words, volumetric efficiency is the ratio between the charge that actually enters the cylinder and the amount that could enter under ideal conditions. Piston displacement is used since it is difficult to measure the amount of charge that would enter the cylinder under ideal conditions. An engine would have 100% volumetric efficiency if, at atmospheric pressure and normal temperature, an amount of air exactly equal to piston displacement could be drawn into the cylinder. This is not possible, except by supercharging, because the passages through which the air must flow offer a resistance, the force pushing the air into the cylinder is only atmospheric, and the air absorbs heat during the process. Therefore, volumetric efficiency is determined by measuring (with an orifice or venturi type meter) the amount of air taken in by the engine, converting the amount to volume, and comparing this volume to the piston displacement.

$$\text{Volumetric efficiency} = \frac{\text{Volume of air admitted to cylinder}}{\text{Volume of air equal to piston displacement}} \times 100$$

The concept of volumetric efficiency does not apply to 2-stroke cycle engines. Instead, the term “scavenge efficiency” is used. Scavenge efficiency shows how thoroughly the burned gases are removed and the cylinder filled with fresh air. As in the case of a 4-stroke cycle engine, it is desirable that the air supply be sufficiently cool. Scavenge efficiency depends largely upon the arrangement of the exhaust, scavenge air ports, and valves.

ENGINE LOSSES

As the heat content of a fuel is transformed into useful work, during the combustion process, many different losses take place. These losses can be divided into two general classifications: thermodynamic and mechanical. The net useful work delivered by an engine is the result obtained by deducting the total losses from the heat energy input.

Thermodynamic Losses

Losses of this nature are a result of the following: loss to the cooling and lubricating systems; loss to the surrounding air; loss to the exhaust; and loss due to imperfect combustion.

Heat energy losses from both the cooling water systems and the lubricating oil system are always present. Some heat is conducted through the engine parts and radiated to the atmosphere or picked up by the surrounding air by convection. The effect of these losses varies according to the part of the cycle in which they occur. The heat of the jacket cooling water cannot be taken as a true measure of heat losses, since all this heat is not absorbed by the water. Some heat is lost to the jackets during the compression, combustion, and expansion phases of the cycle; some is lost (to the atmosphere) during the exhaust stroke; and some is absorbed by the walls of the exhaust passages.

Heat losses to the atmosphere through the exhaust are unavoidable. This is because the engine cylinder must be cleared of the hot exhaust gases before the next air intake charge can be made. The heat lost to the exhaust is determined by the temperature within the cylinder when exhaust begins. The amount of fuel injected and the weight of air compressed within the cylinder are the controlling factors. Improper timing of the exhaust valves, whether too early or too late, will result in increased heat losses. If too early, the valve releases the pressure in the cylinder before all the available work is obtained; if too late, the necessary amount of air for complete combustion of the next charge cannot be realized, although a small amount of additional work may be obtained. Proper timing and seating of the valves is essential in order to maintain heat loss to the exhaust at a minimum.

Heat losses due to imperfect or incomplete combustion have a serious effect on the power that can be developed in the cylinder. Because of the short interval of time necessary for the cycle in modern engines, complete combustion is not possible; but heat losses can be kept to a minimum if the engine is kept in proper adjustment. It is often possible to detect incomplete combustion by watching for abnormal exhaust temperatures and changes in the exhaust color, and by being alert for unusual noises in the engine.

Mechanical Losses

There are several kinds of mechanical losses, but all are not present in every engine. The mechanical or friction losses of an engine include bearing friction; piston and piston ring friction; pumping losses caused by operation of water pumps, lubricating pumps, and scavenging air blowers; power required to operate valves; etc. Friction losses cannot be eliminated, but they can be kept to a minimum by maintaining the engine in its best mechanical condition. Bearings, pistons, and piston rings should be properly installed and fitted, shafts must be in alignment, and lubricating and cooling systems should be at their highest operating efficiency.

CHAPTER 6

REFRIGERATION AND AIR CONDITIONING

As an EN1 or ENC you have already learned the principles of refrigeration and air conditioning, and the components and accessories that make up the system. You have learned how to start, operate, and secure refrigeration plants. In addition, you have performed routine maintenance jobs such as trouble shooting, and servicing the system, and used correct procedure's for leak detecting, 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 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.

You should refer to the manufacturer's technical manual for details of the plant on your ship.

The main parts of an R-12 refrigeration system are shown in figure 6-1. The primary components of the system are the thermostatic expansion valve, the evaporator, the compressor, the condenser, and the receiver. Additional equipment required to complete the plant includes piping, pressure gages, thermometers, various types of control switches and control valves, strainers, relief valves, sight-flow indicators, dehydrators, and charging connections.

In the following discussion, we will deal with the R-12 system as though it had only one evaporator, one compressor, and one condenser. However, a refrigeration system may (and usually does) include more than one evaporator, and it may include additional compressor and condenser units.

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 is a high speed, continuous running unit with a variable capacity. This compressor is of the multicylinder, reciprocating design, with a positive unloaded system built into the compressor to control the compressor's capacity.

SHAFT SEALS

Where the crankshaft extends through the crankcase, a leakproof seal must be maintained to prevent the refrigerant and oil from escaping and also to prevent air from entering the crankcase when the pressure in the crankcase is lower than the surrounding atmospheric pressure. This is accomplished by crankshaft seal assemblies. There are several types of seals including the rotary seal, and the diaphragm.

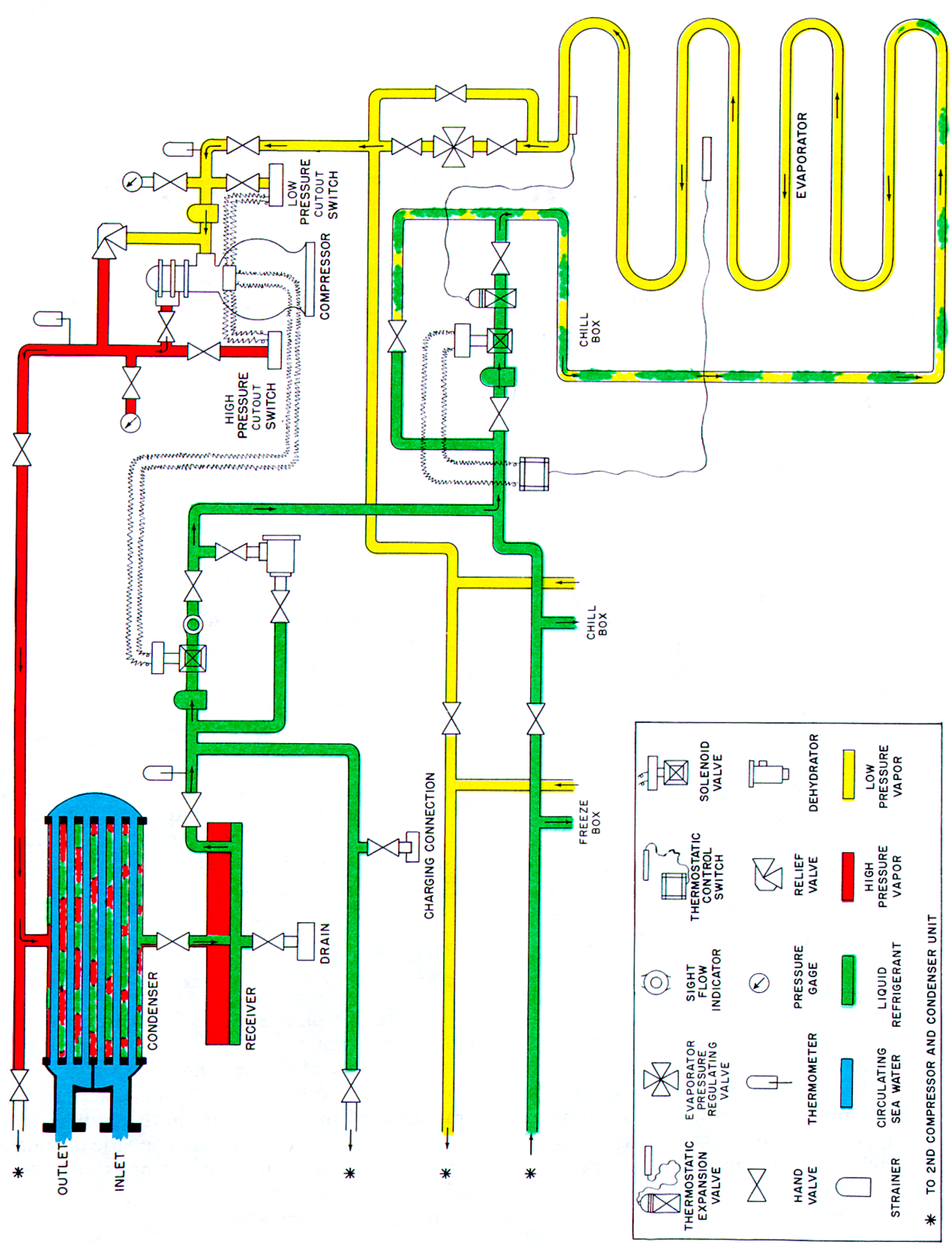


Figure 6-1.—Diagram of an R-12 refrigeration system.

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The rotary seal shown in figure 6-2 consists of a stationary cover plate and gasket, a rotating assembly which includes a carbon ring, a neoprene seal, a compression spring, and compression washers. The sealing points are located (1) between the crankshaft and the rotating carbon rings, and sealed by a neoprene ring; (2) between the rotating carbon ring and the cover plate, and sealed by lapped surfaces; and (3) between the cover plate and the crankcase, and sealed by a metallic gasket. The seal is adjusted by adding or removing metal washers between the crankshaft shoulder and the shaft seal compression spring.

A stationary bellows seal is illustrated in figure 6-3. It consists of a bellows clamped to the compressor housing at one end to form a seal against a rotating shaft seal collar on the other. The sealing points are located (1) between the crankcase and the bellows, and sealed by the cover plate gasket; (2) between the crankshaft and the shaft seal collar, and sealed by a neoprene gasket; and (3) between the surface of the bellows nose and the surface of the seal collar, and sealed by lapped surfaces. The stationary bellows seal is factory set for proper tension and should not be altered.

The rotating bellows seals, figure 6-4, consists of a bellows clamped to the crankshaft at one end to form a seal against a stationary, removable shaft seal shoulder on the other end. The sealing points are located (1) between the crankshaft and bellows, and sealed by a shaft seal clamping nut; (2) between the removable shaft seal shoulder and the crankcase and sealed by a neoprene gasket; and (3) between the bellows nose piece and the shaft seal collar, and sealed by lapped surfaces. This type seal is also factory set.

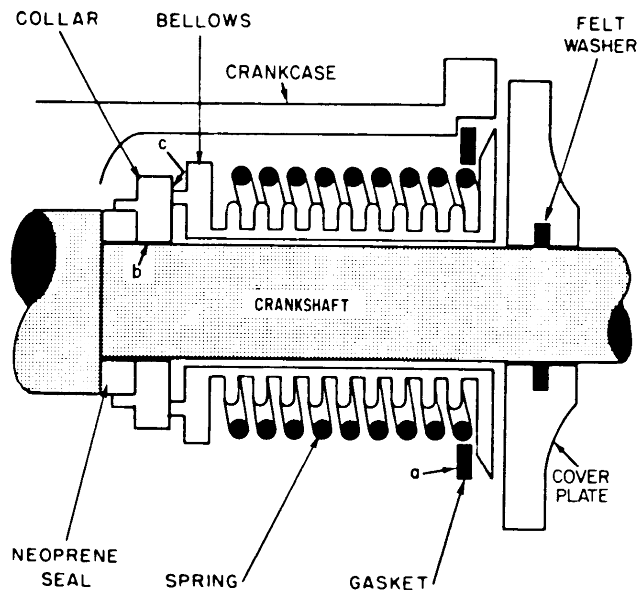

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Figure 6-3.—Stationary bellows seal.

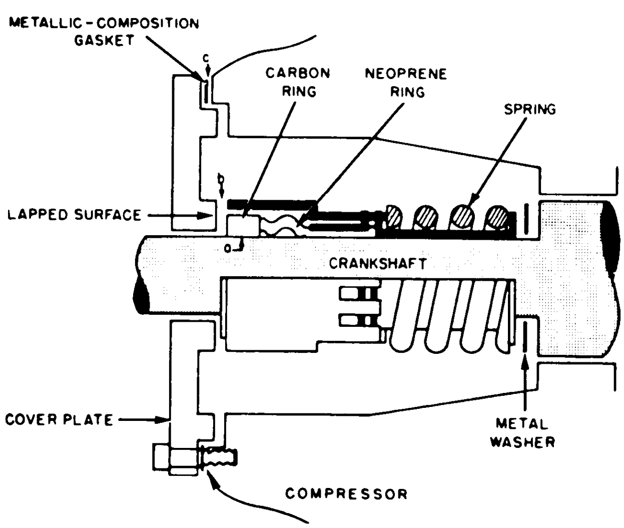

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Figure 6-2.—Rotary seal.

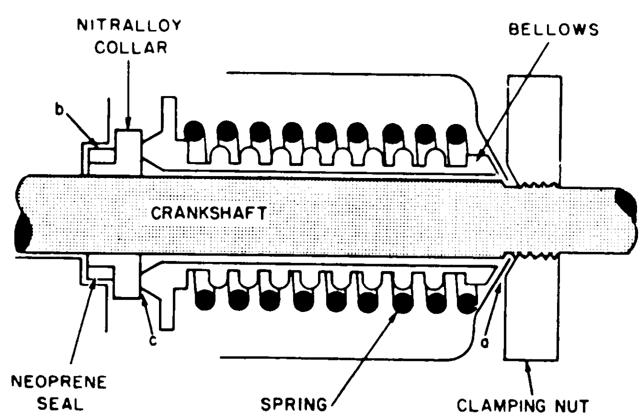

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Figure 6-4.—Rotating bellows seal.

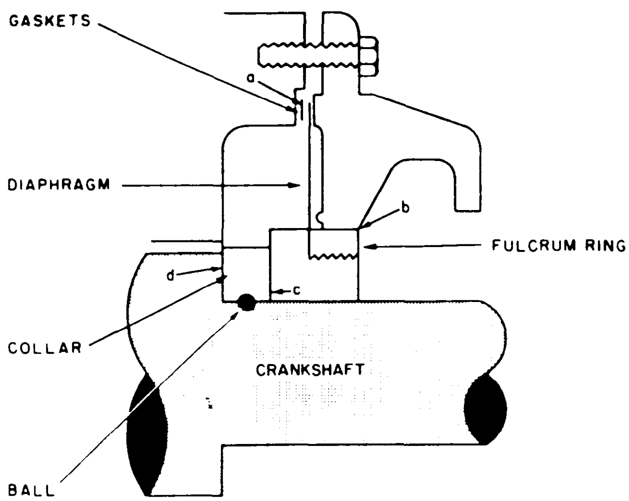

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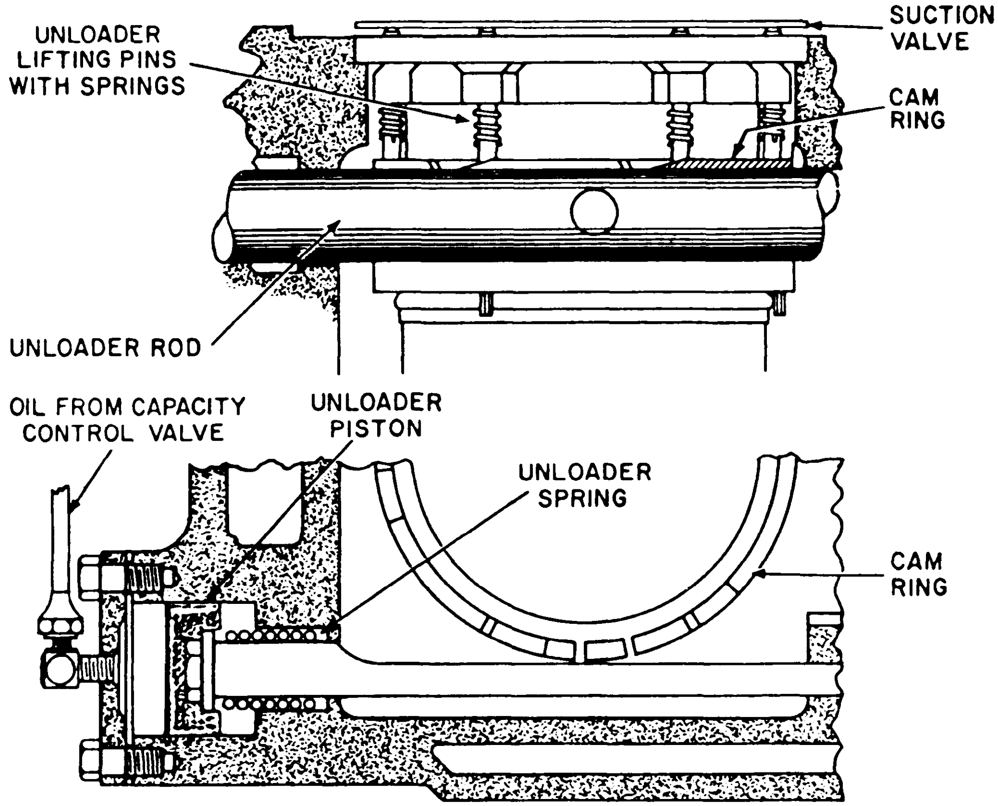
Figure 6-5.—Diaphragm type seal.

The diaphragm seal, figure 6-5, consists of a diaphragm clamped to the crankcase at its outer circumference and to a fulcrum ring at its center. The fulcrum ring forms a seal collar which is locked to the diaphragm. The sealing points are located (1) between the outer circumference of the diaphragm and the crankcase, and sealed by a copper ring gasket; (2) between the fulcrum ring and the diaphragm—sealed at the factory and not to be broken; (3) between the fulcrum ring and the rotating shaft seal collar, and sealed by lapped surfaces; and (4) between the shaft seal collar and the crankshaft shoulder, also sealed by lapped surfaces.

The tension in a diaphragm seal is adjusted by adding or removing diaphragm-to-crankcase gaskets to obtain the specified deflection. For information on handling, cleaning, and replacement of shaft seal assemblies, consult the



121.34

Figure 6-6.—Unloader mechanism in unloaded position.

manufacturer's technical manual or the directions enclosed with every new seal.

CAPACITY CONTROL

Controlling the capacity of the compressor is accomplished by unloading and loading the cylinders. This is a very desirable design feature of the unit, because if the compressor is to be started under a load (all cylinders are 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 and will 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 little as 25% of its rated capacity.

Unloader Mechanism

When the compressor is not in operation, the unloader power element mechanism, which is operated by oil pressure from the capacity control valve, is in the unloaded position (figure 6-6). 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 (figure 6-7). On most compressors unloaders are connected to the cylinders in pairs.

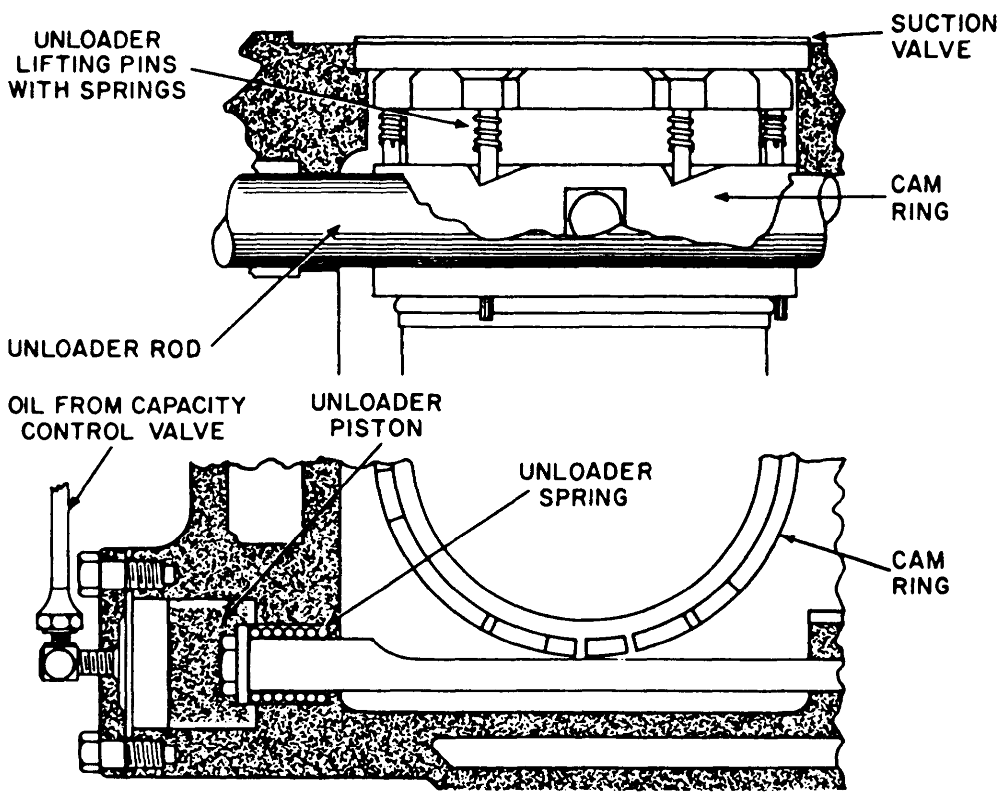


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Figure 6-7.—Unloader mechanism in loaded position.

Capacity Control Valve

The capacity control valve (figure 6-8) is located in the 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. When the compressor is at rest the two cylinders equipped with the unloader element are unloaded and remain unloaded until the compressor is started and the oil pressure reaches normal operating pressure.

As 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, it forces 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 contact with the unloader connections. This admits high pressure oil to the unloader cylinder, actuating the unloader mechanism.

To control the oil pressure from the capacity control valve, a capacity control regulating needle valve is installed. It is connected to the crankcase and 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 needle valve opens and relieves the oil pressure from chamber B of the capacity control valve. 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 action relieves the 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 needle valve relieves more oil pressure and more cylinders become unloaded. On the other hand, if the heat load increases, the suction pressure increases, causing the regulating needle valve to close and more cylinders to become loaded.

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 first to close the suction and discharge valves and then following all safety precautions, to allow all the refrigerant in the compressor to vent to the atmosphere through a drain plug.

When it becomes necessary to remove, replace, or repair any internal parts of the compressor, observe the following precautions:

1. Carefully disassemble and inspect while removing all parts, noting their correct relative position so that errors will not be made when reassembling.
2. Inspect all parts that become accessible after the removal of those 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 the 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 the 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. Take care not to score the gasket surfaces.
8. Renew all gaskets.
9. Clean the crankcase and renew the oil following correct procedures.

EVACUATING THE COMPRESSOR

In all but emergency situations it is desirable to evacuate the compressor with a vacuum pump rather than with the compressor itself. However, if you do not have a vacuum pump available, use the following procedure:

1. Disconnect the 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.

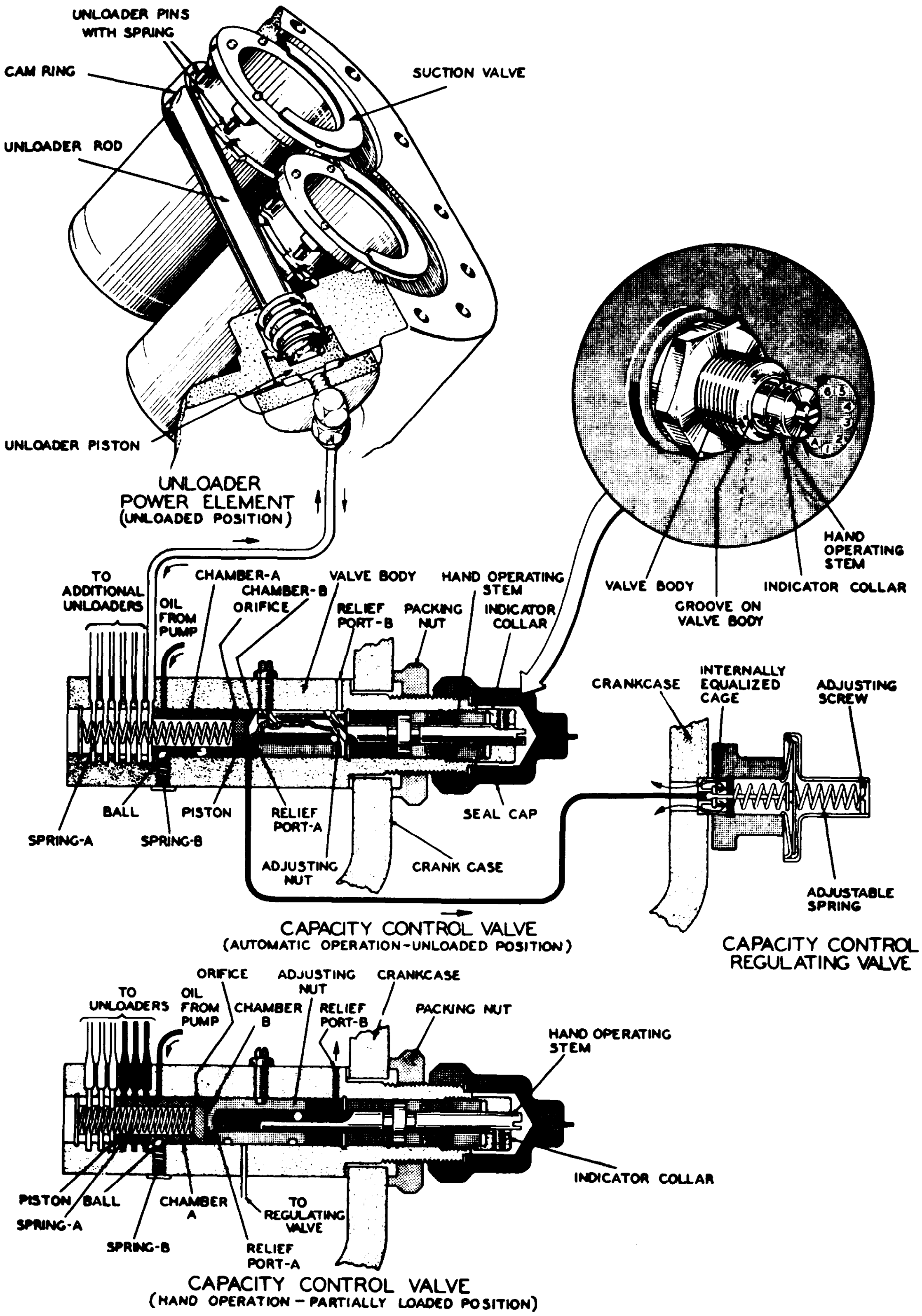


Figure 6-8.—Capacity control system. 121.36

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 and after a few days of operation, the strainers will need cleaning. Strainers should be inspected frequently during the first few weeks of plant operation, and then cleaned as found necessary.

The suction strainers are located either in the compressor housing or in the suction piping. The procedure for cleaning a strainer is as follows:

1. Pump down the compressor.
2. Slowly bleed pressure from unit.
3. Remove the strainer and inspect it for foreign matter.
4. Clean the strainer screen by dipping it in an approved solvent and then allow it to dry.
5. Replace the strainer and evacuate the air from the compressor.
6. Test the housing for leaks by wiping up all oil and then using a halide leak detector.

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 is 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 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 either 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 you remove the condenser heads, 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 when necessary, by using any approved method. Use rubber plugs and an air or water lance when it is necessary to remove foreign deposits. Although it is essential that the tube surfaces be kept clear of particles of foreign matter, care must be taken not to destroy the thin protective coating on the inner surfaces of the tubes. When 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 into the R-12 system.

CLEANING AIR-COOLED CONDENSERS

Although the large plants are equipped with water-cooled condensers, the 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 a condenser should be kept free of dirt and any matter that might obstruct heat flow and air circulation. Brush the finned surface clean with a stiff bristle brush as often as necessary. Use low pressure air to remove dirt in hard to reach places on the condenser. When installations are exposed to salt spray and rain through open doors or hatches, take care to minimize corrosion of the exterior surfaces.

TESTING FOR LEAKS

To prevent serious loss of refrigerant through leaky condenser tubes, test the condenser for leakage every week. Any condenser that has not been in use for the preceding 12 hours should also be tested.

To test for leaky condenser tubes, drain the water side of the condenser and let stand for 12 hours, then 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, you need to detect the exact location of the leak in the following manner:

1. Remove the condenser heads.
2. Clean and dry the tube sheets and the ends of the tubes.
3. Start at the top and work your way down the tube sheet.
4. Check both ends of each tube with a leak detector.

Mark the tubes which show an indication of leakage. If you cannot determine if the tube is leaking internally or around the tube sheet joint, plug the suspected tube with a cork or a similar device and again check around the tube sheet joint. Mark adjacent tubes, if necessary, to isolate the suspected area.

5. 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 cork 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 all leaky tubes for later repairs.

RETUBING CONDENSERS

The general procedure for retubing condensers is outlined in *Naval Ships' Technical Manual* chapter 516. The procedures are given in the applicable manufacturer's technical manual when a condenser of a specific type is being retubed.

CHECKING CONDENSER PERFORMANCE

An overall check for water-cooled condenser performance may be used after, AND ONLY AFTER, the condenser has been properly purged. After the condition of the condensing surface has been determined, prepare the system as outlined in the procedure used to check for noncondensable gases discussed earlier in the chapter. Then proceed as follows:

1. While the compressor is in operation, record the condensing temperature which corresponds to the pressure in the condenser.
2. Record the temperature of the water leaving the condenser.
3. Subtract the temperature of the water leaving the condenser from the condensing temperature. (The temperature of the water leaving the condenser should be several degrees below the condensing temperature of pure R-12.)
4. If the difference between the temperature of the water leaving the condenser and the condensing temperature is 5° to 10°F above the temperature difference obtained when the condenser was in good condition and operating under similar heat loads, and if this difference is not caused by an overcharge of refrigerant or noncondensable gases, clean the water side of the condenser.

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 there is no such temperature difference 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. Any major trouble can usually be traced to moisture or dirt collecting at the valve seat and at the orifice.

TESTING AND ADJUSTMENT

Thermostatic expansion valves used in most shipboard systems can be adjusted by means of a gear and screw arrangement, (superheat to adjustment), maintain a superheat ranging approximately from 4° to 12 °F at the cooling coil outlet. The proper superheat adjustment varies, of course, with the design and the service operating conditions of the valve, and the design of a particular plant. Increased spring pressure increases the degree of superheat at the coil outlet; decreased pressure on the other hand, has the opposite effect. Many thermostatic expansion valves are initially adjusted by the manufacturer to maintain a predetermined degree of superheat, and no provisions are made for further adjustments in service.

When the expansion valves are adjusted to give a high degree of superheat at the coil outlet, or when a valve is stuck shut, the amount of refrigerant admitted to the cooling coil is reduced. With an insufficient amount of refrigerant, the coil is "starved" and operates at a reduced capacity. Compressor lubricating oil carried with the refrigerant tends to collect at the bottom of the cooling coils, thus robbing the compressor crankcase, and providing a condition whereby slugs of lubricating oil are drawn back to the compressor. If an expansion valve is adjusted for too low a degree of superheat, or if the valve is stuck open, the 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 will be 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) 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, make appropriate tests. (First make 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, is useful in showing the pressure on the inlet side of the valve. Normally, refrigeration plants are provided with suitable replacement and test pressure gages.

The procedure for testing is as follows:

1. Connect the valve inlet to the gas supply with the high pressure gage attached to indicate the gas pressure to the valve, and the low pressure gage loosely connected to the expansion valve outlet. The low pressure gage must be 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 perform this test with a container full of water in which only 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.

4. Adjust the expansion valve, if it is desired to adjust for 10°F superheat, the pressure on the outlet gage should be 22.5 psig. This pressure is equivalent to the pressure of an R-12 evaporating temperature of 22°F. 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. Allow for 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. Tighten the low pressure gage connection and stop the leakage at the joints. Determine if the expansion valve seats tightly. If the valve is in good condition, the pressure will increase a few pounds and then either stop or build up very

slowly. If the valve is leaking, the pressure will build up rapidly until it equals the inlet pressure.

7. Again loosen the gage to permit leakage at the gage connections. 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. 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 whether 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 A VALVE

When an expansion valve is defective, it must be replaced. Some 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, 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 there may be a loss of the refrigerant charge. If this happens, the plant will operate erratically and inefficiently until the cause of trouble is corrected.

HALOCARBON SAFETY

Halocarbons are organic chemical compounds containing one or more atoms of carbon and hydrogen plus one or more atoms of fluorine, bromine, chlorine, or iodine which may be present in various combinations in the compound. You may be more familiar with their brand or trademark names such as: Freon(s), Gentron, Genesolv D, Frigen, AFFF, or carbon tetrachloride. As Enginemen, we work with these refrigerants, solvents, and fire extinguishing compounds regularly aboard ship. The extended and routine usage of halocarbons in the military and civilian environments (e.g., home/car air conditioners) has led us to a false sense of security which makes us forget the inherent poisonous nature of halocarbons, particularly when used in high concentrations in enclosed or confined spaces.

Warnings, hazards, and cautions in technical and training publications are usually benign. The labeling of containers and storage areas are consistently inadequate. The procedures for the disposal of halocarbon waste are not well known nor are they followed. Most people do not know the physiological effects of high concentrations of halocarbons on humans or the recommended first aid by both medical and non-medical personnel.

All Enginemen who handle or use halocarbons must be aware of the hazardous properties of halocarbons. The greatest hazards have been associated with Freon 113 refrigerant and Genetron 113 (a fluorocarbon compound), with the chemical name of TRICHLOROTRIFLUOROETHANE, which is used in large quantities for cleaning refrigeration, hydraulic, air and oxygen systems, and as a solvent for removing oil and grease from machinery. Trichlorotrifluoroethane is a heavy, colorless liquid at room temperature, and has an odor similar to drycleaning fluid. Because of its low boiling-point it evaporates rapidly at room temperature. Its vapor is several times heavier than air and tends to collect in low places.

Trichlorotrifluoroethane should always be treated as a toxic solvent. Exposure to it can cause headache, rapid heartbeat, light-headedness, and tingling of fingers or toes. Any of these symptoms is a warning to leave the area immediately. In higher concentrations the solvent has an anesthetic effect (causing uncoordination and stumbling); it can effect the heartbeat (causing irregular beats or even stoppage) and can cause tremors, convulsions, and DEATH. Refrigerant gases such as Freon 12 and 22 have properties similar to the ones described above except that they are practically odorless and can cause freeze burns.

During all primary maintenance or industrial uses of halocarbons such as flushing or recharging refrigeration or air conditioning systems, the following "good engineering" precautions are mandatory:

1. Strict compliance with NSTM gas-free Engineering directions for entry into enclosed or confined spaces, and close adherence to standard operating procedures for all halocarbon maintenance actions.

2. Tested and operational ventilation systems. Availability of portable equipment to provide intake from—and exhaust to the atmosphere (not recirculation) sufficient to maintain halocarbon concentration at acceptable limits throughout the whole maintenance action. (Example: The limit for continuous exposure to the vapors of Freon 113 is 1000 parts of solvent per million parts of air. This limit will be reached by evaporation of approximately 100 milliliters (less than 1/2 cup) of solvent in a 10 × 10 × 10 ft. space). Local exhaust ventilation capable of maintaining a minimum capture velocity of 100 fpm over the face of the container or operation is normally required in order to maintain the vapor within acceptable limits. Note: Absolutely NO venting of halocarbons below decks shall be permitted.

3. Positive pressure emergency breathing devices with supplied air available in the space for instant donning and egress in the event of a halocarbon mishap.

4. Established two-way communications between the halocarbon pump at the bulk source and the equipment being filled, cleaned, or flushed. A backup sound powered system is recommended.

5. Verification of filling and flushing system integrity by leak testing (e.g., a pressure drop test) before halocarbon operations commence.

6. A minimum of two people should be stationed in the space, with a safety observer (tender) in the vicinity of the egress route if available. Rescue equipment (as necessary) to quickly remove personnel from the space in the event of an emergency. (Rescue personnel should also be equipped with protective clothing and positive pressure respiratory protection.)

7. A medical department representative, who is trained and knowledgeable in the physiological effects, prescribed first aid and emergency treatment methods for halocarbon mishaps, should be alerted to the maintenance action being performed and standing by for quick response.

8. An emergency eyewash/shower system in the immediate vicinity of all halocarbon operations should its use be required. Where a permanent system is not available, a portable system of 5-10 gallon capacity should suffice. Only potable water should be utilized for this purpose.

9. Ship's emergency rescue teams (e.g., "Flying Squads" and repair parties) familiar with the hazards of halocarbons and trained in air-supplied respirator requirements when involved in halocarbon rescue operations.

10. The performance of hot work is prohibited from halocarbon work areas, due to the potential decomposition of halocarbons into more toxic chemicals.

As stated earlier, in high concentrations, halocarbons are toxic chemicals. Any handling or usage of these chemicals requires the following minimum personal protective measures:

1. Full-length face shield or chemical workers goggles
2. Apron or coveralls (both may be required)
3. Elbow length gloves
4. Boots or booties
5. Clothing and equipment must be impervious and resistant to halocarbons.

Note: Non-impervious clothing which becomes wet with halocarbons must be immediately removed and not reworn until all traces of the chemical are removed by cleaning.

CHARGING THE SYSTEM

Information concerning the charging of refrigeration systems may be found in *Naval Ships' Technical Manual* chapter 516. The amount of refrigerant charge must be sufficient to maintain a liquid seal between the condensing and the evaporating sides of the system. When the compressor stops, under normal operating conditions, the receiver of a properly charged system is about 85% 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. A system should be checked for leaks immediately following—or during—the process of charging.

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, close the liquid line stop valve. By-pass all evaporator pressure regulator valves and allow the system to pump down one or more times. Stop the compressor. By-pass the water regulating valve and circulate cooling water through the condenser. When discharge pressure stops dropping, convert the pressure to temperature and from this subtract the temperature of the injection or overboard. (They both should be equalized.) A variation of over 5 °F will indicate that air and noncondensable gases are present in the system. Crack open the purge valve for 2-3 seconds at 2 to 3 minute intervals until the temperature is within 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. Close the strainer outlet valve and very carefully loosen the cap which is bolted to the strainer body. (Use all appropriate safety gear.) When all of the pressure is bled out of the strainer, remove the cap and lift out the strainer screen. Clean the strainer screen with a small brush, using an approved solvent. Reassemble the spring and screen in the strainer body. Replace the strainer cap loosely. Purge the air out of the strainer, by blowing refrigerant through it, then tighten the cap. After 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 installed in the pump discharge line. A gradual decrease in lubricating oil pressure indicates that the units need cleaning. Cleaning is 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 must 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 such factors as refrigerant evaporating temperature, condition of door gaskets, moisture content of supplies placed in boxes, how frequently the doors are opened and atmospheric humidity.

Cooling coils should be defrosted before the frost thickness reaches three-sixteenths of an inch. When defrosting, do not scrape or break off the frost, as this may cause damage to the coils.

EVACUATING AND DEHYDRATING THE SYSTEM

The major cause of system failures is moisture (H_2O) which is brought in through air leaks.

When H_2O combines with R- 12 it forms sulfric acid which will attack the entire system. Good engineering practice dictates that evacuation, dehydration and fixing all air leaks will in the long term prevent an acid attack upon the system.

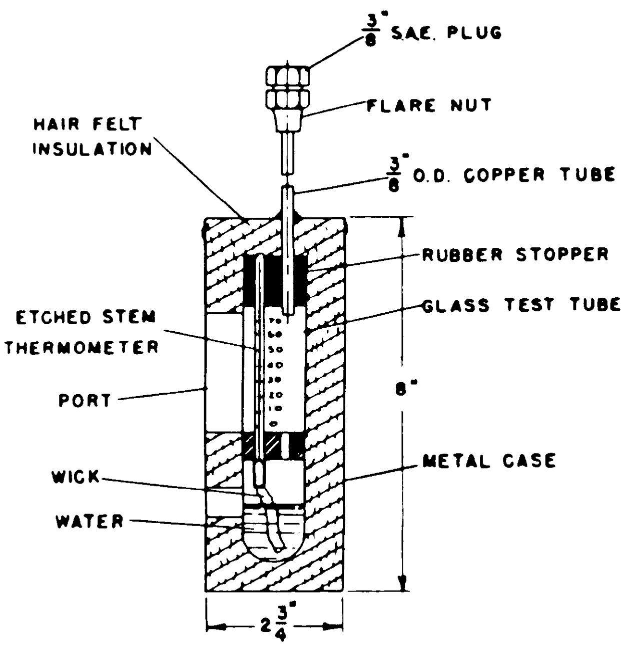
Where moisture accumulation must be corrected, the system should first be cleared of refrigerant and air. The time required for these processes will depend upon the size of the system and the amount of moisture present. It is good engineering practice to circulate heated air through a large dehydrator 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, the remaining moisture is evacuated by means of a two-stage high-efficiency vacuum pump. (These vacuum pumps are available aboard tenders and repair ships.)

A vacuum indicator (figure 6-9) is attached to the two-stage high efficiency pump. It consists of an insulated test tube containing a wet bulb thermometer with its wick immersed in distilled water. This indicator is connected to the vacuum pump suction line, which in turn, is connected to the refrigeration system. The refrigerant circuit should be closed to the atmosphere and the charging connection should be opened to the vacuum pump.

Two-stage pumps are 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 6-10). Readings will initially reflect ambient temperatures. Then they will show rapidly



CONVERSION TEMPERATURE °F TO ABSOLUTE PRESSURE INCHES MERCURY

TEMP. °F	ABS. PRESSURE INCHES MERCURY
60	0.521
55	0.436
50	0.362
45	0.300
40	0.248
35	0.204
32	0.181

96.32

Figure 6-9.—Dehydrator vacuum indicator.

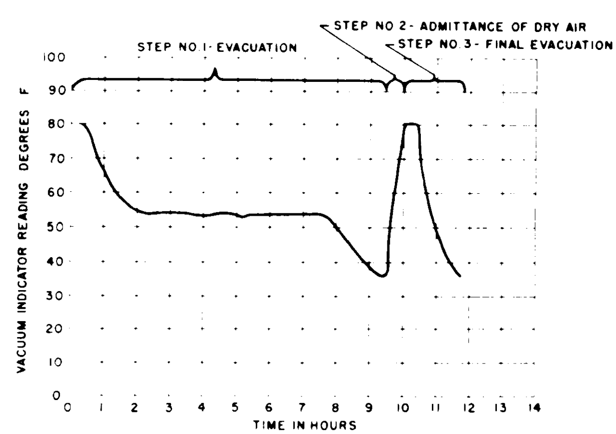


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Figure 6-10.—Vacuum indicator readings plotted during dehydration.

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. As soon as the temperature reaches 35 °F (0.2 inch Hg, absolute), admit dry air through a chemical dehydrator into the system at a point farthest from the pump. As the pump continues operating, the dry air will mix with and dilute any remaining moisture. Secure the opening which feeds the dry air to the system. The system must continue evacuating 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 is impossible to obtain a temperature as low as 35 °F in the vacuum indicator. The probable reasons for this and the corrective procedures to take, are as follows:

1. Excess moisture is present in the system. Because of the acid being formed, the dehydration procedure should be conducted for longer periods.
2. Absorbed refrigerant is present in the lubricating oil contained in the compressor crankcase. Remove the lubricating oil from the crankcase before proceeding with the dehydration process.
3. Air is leaking 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. However, when special drying agents are employed they should be reactivated in accordance with the specific instructions furnished by the manufacturer.

After reactivation, the drying agent should be placed back 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 with a fresh charge, or with a dehydrator cartridge, taken from a sealed container.

Remember that the dehydrators that are 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 procedures 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, insert a hard wool felt filter, about 5/16 inch thick, in the suction strainer screen. The plant should then be operated with an operator in attendance, for at least 36 hours or until cleaned, depending upon the size and the 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 identical, however, the devices used to control space temperatures differ. A two-position control, sometimes called the on/off control, is used for the automatic control of most shipboard air conditioning systems.

TWO-POSITION CONTROL

This control may be used on three types of systems:

1. Systems employing a simple thermostatically controlled single-pole switch to control flow 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 1 system above is the most commonly used and 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 1 system requires single-pole thermostats, the 2PD used in type 2 and type 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 has greatly increased, due to the present effort to make living and working spaces more comfortable and to the rapid development of various types of weapons systems. Such spaces often use a common cooling coil serving several different spaces. Assume that 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 and the cooling thermostats of the various spaces are connected in parallel so that any one may open the cooling coil valve.

Suppose space “B” (figure 6-11) 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%. Where the humidistat is installed, an increase in temperature beyond the thermostat setting will close the thermostat cooling switch and an increase in relative humidity beyond the

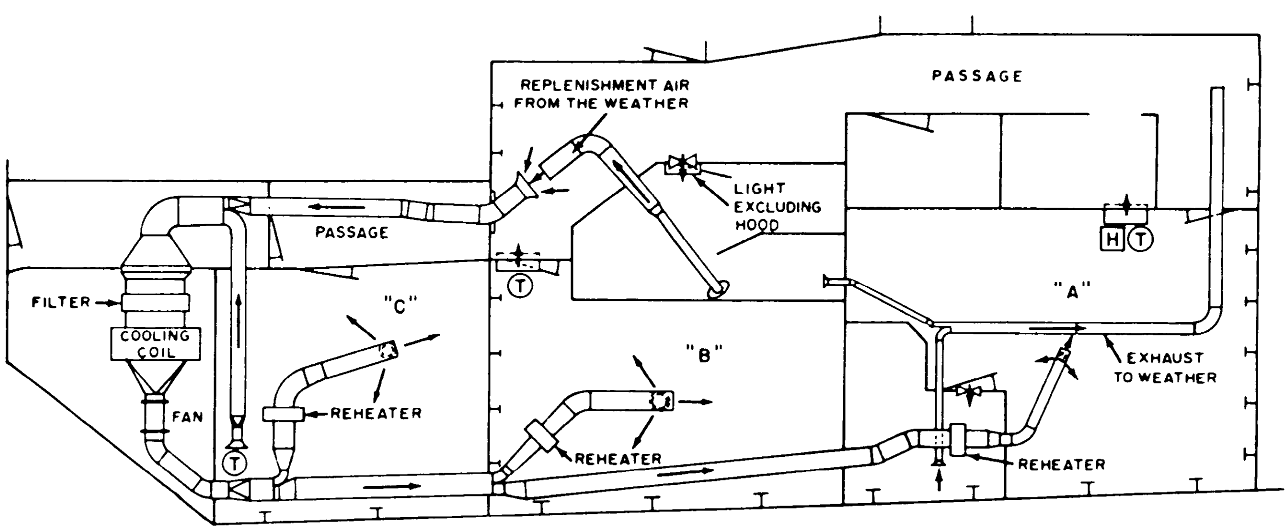

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Figure 6-11.—Typical air conditioning system.

humidistat setting will close the heating switch, energizing the reheaters.

MAINTENANCE

Proper attention to maintenance checks will often allow you to 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 conducted at the beginning of the cooling season and about mid-way. The same should be done for the heating season.

Sensing elements should be inspected and any dust accumulations removed. Thermostatic sensing elements should have dust and dirt removed with a soft brush, and the sensing elements in humidistats should be blown off gently with air so as not to damage the elements.

Magnetic valves should be checked for operation. Be sure that the valves are opening and closing completely.

Setpoints 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 areas where trouble may occur:

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 6-12 and 6-13 indicates some possible troubles that may be encountered, the possible causes of these troubles, and the corrective action which may be taken. But remember always consult the manufacturer's technical manual before attempting any repair or adjustment on your equipment.

Trouble	Possible Cause	Corrective Measure
High condensing pressure.	Air or non-condensable gas in system.	Purge air from condenser.
	Inlet water warm.	Increase quantity of condensing water.
	Insufficient water flowing through condenser.	Increase quantity of water.
	Condenser tubes clogged or scaled.	Clean condenser water tubes.
	Too much liquid in receiver, condenser tubes submerged in liquid refrigerant.	Draw off liquid into service cylinder.
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 refrigerant charge
	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 6-12.—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 moirture 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. 2. 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 6-12.—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.

54.299.3

Figure 6-12.—Trouble diagnosis chart-Continued.

TROUBLE	POSSIBLE CAUSE	TEST	REMEDY
Space temperature higher than thermostat setting and thermostat contacts are open.	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 thermostat lower than thermostat setting and contacts are closed.	Bad location of thermostat (this will also effect cooling).	Test with reliable thermometer at location.	Move thermostat to a better location.
Space temperature lower than thermostat setting and thermostat contacts are open.	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 low, 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.

Figure 6-13.—Trouble diagnosis chart.

CHAPTER 7

AUXILIARY MACHINERY

Information related to much of the auxiliary machinery aboard ship is provided in *Engineman 3 & 2,* NAVEDTRA 10541 (current revision). This chapter provides additional information on the care and maintenance of compressed air systems and equipment, auxiliary boilers, hydraulic systems, distilling plants and pressure valves.

COMPRESSED AIR SYSTEMS

Qualifications for lower rates require that you know not only the purpose and principles involved, but also the operation and performance of routine maintenance on many auxiliary systems and units which use compressed air. As an EN, you have already used compressed air for such jobs as starting diesel engines, blowing out and cleaning various units, and operating numerous pneumatic tools. When working with any of the three types of compressed air systems (low, medium, and high pressure), you have probably found that the principal source of many troubles is to be found in the compressor. Even though the design and capacity of compressors vary, the maintenance procedures are essentially the same for all of them. However, the care and maintenance of high pressure compressors require additional safety precautions and adherence to procedures recommended by the manufacturer.

Because of your past experience, parts of the following discussion will serve only as a review, while other portions of the discussion will benefit you in your study for advancement, and will be helpful when you are called upon to train others.

To avoid unnecessary damage to equipment, always use proper tools and take all necessary precautions. The correct use of proper tools should be kept constantly in mind when a machine of any kind is being serviced. Remember, the improper use of tools and methods may cause serious casualties to both machinery and personnel.

Although rugged and dependable, modern auxiliary machinery 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. Whenever a joint or bolt cannot be tightened without the use of an oversized wrench or wrench handle extension, there is usually something wrong with the assembly.

Pounding on a wrench to acquire additional force usually results in damage to the equipment. Use of a wrench extension is likely to distort the gasketed surface or twist off the bolt without achieving a tight joint. The application of any force in excess of the force prescribed usually results in breakage.

CARE AND MAINTENANCE OF AIR COMPRESSORS

To keep the ship's air compressors 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 and couplings; and how to properly maintain the lubrication, the cooling, the control, and the air systems.

Air Intakes and Intake Filters

The satisfactory operation of any compressor is based on a supply of clean, cool, dry air. To aid in keeping the air supply clean, filters are fitted to compressor intakes. Unless inspected and cleaned regularly, these filters become clogged and cause a loss of capacity.

Filter elements should be removed from the intake and cleaned either with a jet of hot water or steam, or by immersion in a strong solution of sal soda. The filter body should be drained and replaced. Filter elements of the oil-wetted type should be dipped in a clean, medium viscosity oil after cleaning and the excess oil should be drained from the elements before replacing them on the filter intakes. Gasoline or kerosene should not be used for cleaning air filters because of the explosive fumes which may collect in the compressor or air receiver.

Dehydrators

On some ships, compressed air is used for the operation of missile system components and with automatic controls for boilers. In order to prevent failure of these systems, moisture and lubricants from the compressor must be kept at a minimum. Blowing down the compressor separators prevents most of this, but still some moisture is carried over.

To aid in the removal of the moisture and lubricants, two types of dehydrators are generally used: type I refrigerant dehydrators and type II dehydrators using a desiccant of either silica gel or activated alumina, and containing electric heating coils for reactivating the desiccant when it becomes saturated with moisture. Type II dehydrators are normally installed in pairs so that one can always be in service while the other is being reactivated.

Air Valves

Air inlet and discharge valves are vital parts of a compressor and should receive careful attention. When these valves leak, the compressor capacity is reduced and results in an unbalanced stage pressure.

There are several symptoms which signify that an air valve is not functioning properly. A deviation from normal intercooler pressure may indicate a leaking or broken valve. A defective inlet valve above the intercooler will cause a rise in pressure in the intercooler, while a defective discharge valve below the intercooler will cause a decrease in the intercooler pressure. An unusually hot valve cover is a sign of valve trouble.

Dirt is generally the cause of leaking valves. The source of valve trouble can usually be traced to dirty intake air; the use of excessive or improper cylinder oil; or excessively high air temperature, resulting from faulty cooling. A periodic inspection and cleaning of valves and valve passages will minimize and perhaps prevent the occurrence of air valve troubles. The frequency for cleaning valves must be determined for each installation.

The air valves are easily accessible and are removed by first loosening the valve cover plates. Then the valve and valve unloader, if installed, may be lifted out. Each valve should be marked so that it may later be returned to the same opening from which it was removed.

Dirt or carbon can usually be removed from valve parts without disassembling the valve. If disassembly is necessary, notice should be taken on how the various parts are arranged so that the proper relationship will be kept when the valve is reassembled. To remove carbon from valve parts, soak each part in kerosene and then brush or scrape lightly. After drying and reassembling the valve parts, test the valve action to be sure that the valve opens and closes freely.

Before air valves are replaced in a cylinder, inspect the gaskets. If the gaskets are made of materials other than copper, and are damaged, change them. Copper gaskets should always be replaced. Since it is often difficult to distinguish between suction and discharge valves, use extreme care when inserting valves in the cylinder. Make sure that suction valves open TOWARD, and discharge valves AWAY FROM, the center of the cylinder. Otherwise, serious damage or loss of capacity will result. If special locknuts are not provided to seal against leakage at the threads of the valve setscrew, place a turn of solder or fuse wire around the screw and set down into a recess by the locking nut.

Cylinders and Pistons

When you find that it is necessary to inspect the cylinders or pistons of an air compressor, you should refer to the manufacturer's instruction manual and the appropriate Planned Maintenance System (PMS) maintenance requirement card

(MRC) for the proper methods and tools required for removing the heads. The following is general information on removing a piston, fitting new piston rings, and checking piston end clearance for a vertical compressor.

To remove trunk pistons from vertical compressors, it is first necessary to remove the cylinder heads. In the case of three- or four-stage compressors, the third and fourth stage cylinders will also have to be removed. Next, you must turn the compressor by hand to top center and remove the lower half of the crank pin bearing, or the entire crank pin bearing box, if so directed. Pull up the piston and connecting rod through the cylinder. In removing pistons from compressors fitted with cross heads and piston rods, the general procedure is to loosen the piston rod locknuts adjacent to the cross head, then unscrew the piston rod from the cross head and lift the piston and the rod out of the cylinder.

If the piston rings are worn or broken and require replacement, take accurate measurements of the cylinder or liner to determine the exact diameter. Standard size rings may be used in oversize cylinders if the oversize does not exceed 0.003 inch per inch of the cylinder diameter. If the cylinder or liner is worn beyond the manufacturer's recommended limits, it should be replaced. On compressors not equipped with liners, such as air-cooled or large pneumatic service compressors, one reboring is allowed.

When piston rings are being replaced, they should first be fitted to the cylinder to check for proper end clearance. If necessary, the ends should be filed until the manufacturer's recommended clearance is obtained. Rings should then be fitted to the piston grooves, making sure that the side clearance of each ring is such as to allow it to fall into the groove by its own weight. The thickness of each ring should be checked to make sure that the groove is deep enough for the ring thickness. In replacing the rings, care must be taken to ensure that they are staggered so that the ring splits are not in line. After the piston is assembled, it is advisable to wire the rings tightly with a soft copper wire so that they will enter the bore without difficulty. As each ring enters the bore, the binding wire can be removed through the valve ports. Most cylinder liners are beveled at the top to permit the rings to compress and enter the bore easily. In certain designs of differential pistons, it is necessary to loop a wire around the top of the lower liner, using valve ports for access, and squeeze each ring closed as it approaches the top of the liner. One technique is to slip the rings over a thin piece of shim stock which, in turn, is slipped over the piston. This prevents overstretching and other possible ring damage.

After a piston has been replaced in a compressor and the head has been drawn down evenly, it will be necessary for you to check piston end clearance. NOTE: The piston end clearance must always be measured and adjusted after replacing the pistons, or after any adjustment or replacement of the main, crank pin, wrist pin, or cross head bearing has been made. This is accomplished by inserting a lead wire through a valve port or indicator connection, and then jacking the compressor over so that when the piston has moved to the end of its stroke (top dead center (TDC)), the lead will be flattened to the exact amount of clearance at the end of the stroke. The lead wire should be long enough so that the reading can be taken at a point near the center of the piston.

In differential piston compressors in which compression takes place in two stages during the same stroke, the clearance must be measured for both stages. In double-acting compressors, or in those compressors in which compression in any stage takes place on the reverse stroke, a second reading of the clearance at the bottom of the stroke (bottom dead center (BDC)) of that cylinder must be taken.

After taking these readings, you can adjust the piston end clearances. Proper clearances for a specific compressor are usually found in the manufacturer's instruction book or on the blueprints. If neither of these documents is available, then you should adjust the clearance so that the TDC stroke is approximately 1/64 inch greater than the BDC stroke. This is necessary to allow for the expansion of the running parts when the compressor is in operation.

The method of adjusting the piston clearance varies with different compressors or designs. Adjustments may be accomplished by one of the following methods: (1) by adding or removing shims in the connecting rod between the lower end of the rod and the crank pin bearing boxes; (2) by adding or removing shims between piston and socket type wrist pin boxes; (3) by screwing in or backing out the wrist pin adapter, in compressors having a threaded wrist pin adapter; (4) by turning the piston rod in or out of the cross head, in double-acting pistons equipped with piston rod and cross head. In some compressors, the piston clearance is nonadjustable.

Control Devices

Because of the great variety of control, regulating, and unloading devices used with compressors, detailed instructions on their adjustment and maintenance must be obtained from manufacturers' technical manuals.

When a control valve fails to work properly, disassembly and a thorough cleaning is usually 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 and to remove gummy deposits which come from the oil used in the compressor cylinders. Replace the filter element with the specified material each time a valve is cleaned.

WARNING: DO NOT use cotton as a filter element because it will pack down and stop the air flow.

Since relief valves are essential for the safe operation of a compressed air system, they must be kept in satisfactory working condition at all times. Relief valves should be set as specified by the manufacturer, and tested by hand each time the compressor is started. Periodically, the setting of relief valves should be checked by raising the pressure in the space which they serve.

Lubricating and Cooling Systems

The maintenance procedures for lubricating and cooling systems in air compressors are similar to the procedures used for lubricating and cooling systems in internal combustion engines. For air-cooled compressors, steps must be taken to keep the cooling fins clean. Oil and dust act as insulators and, if allowed to collect on the fins, will prevent heat transfer.

In general, the lubricating system of a compressor will give you little trouble if the following steps are taken:

1. Keep the reservoir oil at the prescribed level in order to maintain proper oil temperature.
2. Change crankcase oil periodically, flush the crankcase, and clean the oil filter.
3. Maintain proper lube oil pressure by keeping the oil pump in good working condition and by adjusting the bypass relief valve.
4. Keep the oil cooler free from leaks to prevent oil contamination and emulsification.
5. Inspect cylinder lubricators.

   a. When Navy Symbol 9000 series oil is used for compressor cylinder lubrication, the sight flow indicators should be filled with glycerine alone.

   b. When Navy Symbol 2000 series oil is used for cylinder lubrication, the sight flow indicators should be filled with a mixture of 50% distilled water and 50% glycerine.

6. Keep the lubricator in proper adjustment for the specified quantity of oil feed.

The general requirements for care and maintenance of compressor cooling systems are as follows:

1. Intercoolers and aftercoolers should be inspected periodically.
2. Collections of gummy oils or tarry substances on the sides of cooler tubes should be removed by washing the tube nests with a cutting solution. Be sure that the nests are completely dry before reassembly.
3. Any leaks in tube nests must be repaired; otherwise, water will leak into the compressor while it is secured, and air will leak into the water side during operation.

If during operation, a water relief valve on the coolers blows while the cooling water pressure is normal, it is evident that a tube in the cooler is ruptured. The compressor should be secured immediately and the tube plugged, if possible.

4. Cylinder water jackets should be inspected and cleaned periodically with a cleaning nozzle.

5. When the cooling water system of the compressor is being refilled, the water inlet valve should be opened slightly to allow the water to rise slowly in the cooler shell and water jackets. Also, the vent valves which are fitted to the water spaces should be opened to permit entrapped air to escape, and thus prevent the formation of air pockets in the system.

CARE AND MAINTENANCE OF AIR SYSTEM EQUIPMENT

The air flasks and separators of surface ships must be given a surface inspection every 3 months to determine if there is any external corrosion or damage to flasks or piping.

Because of the coating of zinc chromate primer, corrosion is seldom a source of trouble on the internal surfaces of air flasks; however, corrosion may take place on the external surfaces of air flasks and may be sufficiently serious to weaken the material, especially in high-pressure flasks. Surface corrosion usually occurs at points which cannot be easily reached for proper cleaning and painting.

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 since any excessive oil accumulation may result in an explosion.

All high-pressure flasks and separators must be inspected, cleaned, tested, and repainted at prescribed intervals by a repair activity. For surface ships, the initial and subsequent intervals should not exceed 6 years. Although inspection intervals for separator flasks are approximately 3 years, if there is reason to believe that serious corrosion of either the exterior or the interior of air flasks is taking place, before the lapse of the normal interval, the flasks should be inspected and tested at once.

Periodic examinations are essential to determine the condition of air system equipment; these examinations should include not only a complete inspection of the interior and the exterior of flasks and separators, but also ultrasonic inspections and hydrostatic tests. After a thorough cleaning, the flasks which successfully pass the hydrostatic test are given the prescribed internal protective coating, and when necessary, the exterior is painted. Further information on the details of the inspections and maintenance performed by repair activities can be found in chapter 551, section VIII, of *Naval Ships' Technical Manual.*

INSPECTIONS AND TESTS

The minimum maintenance requirements for the performance of inspections and tests of compressed air plants are given in figure 7-1. 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 each test and inspection are obtained from the PMS Manual, or the appropriate manufacturer's technical manual.

SAFETY PRECAUTIONS

Competent personnel operating and maintaining any machine keep it performing as efficiently as possible. In order to achieve peak performance from a compressed air plant, they take steps to prevent or minimize the occurrence of any condition which might reduce plant capacity or result in serious damage. All personnel should take every possible precaution to prevent potential explosions, especially when operating high pressure systems. Safety precautions which will aid you in preventing explosions and in maintaining a plant in satisfactory operating condition are listed below.

1. Minimize the possibility of explosions in an air compressor, discharge line, or receiver by taking steps to prevent or eliminate the following:

   a. Dust-laden intake air.
   b. Presence of oil vapor in compressor or receiver.
   c. Leaking or dirty valves.

2. Make sure that the compressor intake receives only cool, dry air.

3. Use only prescribed agents for cleaning compressor intake filters, cylinders, or air passages. DO NOT use benzene, kerosene, or

System, Subsystem, or Component	Reference Publications and/or Maintenance Significant Number
Compressed air plant	

Bureau Card Control No.					Maintenance Requirement	M.R. No.	Rate Req'd.	Man Hours	Related Maintenance
AP	ZZ7FCH3	C3	1320	D	1. Inspect crankcase oil level. 2. Drain intercooler and aftercooler separators.	D-1	FN	0.2	None
AP	ZZ7FCH3	C3	1321	W	1. Operate compressor by power. 2. Blow down air flasks. 3. Sample and inspect lube oil.	W-1	FN	0.5	None
AP	ZZ7FCH3	C3	1322	M	1. Lift relief valves by hand. 2. Drain and clean crankcase.	M-1	EN3 FN	1.0 1.0	None
AP	ZZ6FFC1	C3	1323	Q	1. Clean air suction filter.	Q-1	EN3	0.5	None
AP	ZZ7FCH3	C3	1324	Q	1. Remove and clean tube bundles intercooler and aftercooler.	Q-2	EN3	1.5	None
AP	ZZ7FCH3	93	0291	Q	1. Sound and set up foundation bolts. 2. Visually inspect air flasks, separators and piping for corrosion.	Q-3	FN	0.2	None
AP	ZZDFGA0	93	0292	A	1. Calibrate gauges.	A-1	EN3	0.2 per gauge	None
AP	ZZ7FCH3	93	0293	A	1. Test air system under full working pressure.	A-2	EN2	1.5	W-1
AP	ZZ7FCH3	C3	1325	C	1. Inspect internal parts for wear.	C-1	EN2 FN	16.0 16.0	None
AP	ZZRFVA1	C3	1326	C	1. Test relief valves by pressure.	C-2	EN3	0.5 Per Valve	None

Bureau Page Control No. E-26
3

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Figure 7-1.—PMS tests and inspections for compressed air plants.

other light oils that vaporize easily and that, under compression, form a highly explosive mixture.

4. Use only the minimum amount and the proper grade of oil for cylinder lubrication.

5. Secure a compressor immediately if there is an abnormal rise in the temperature of air discharge from any stage.

6. Be sure a relief valve is installed between a compressor and a stop valve, or a check valve is installed between a compressor and the receiver. If there is no relief valve and the compressor is started against a closed valve or a deranged check valve, the air will not be able to escape and an explosion will result.

7. Do not leave a compressor station after starting a compressor, especially a new compressor or one that has been idle for some time, until you are positive that the control, unloading, and governing devices are working properly.

8. Do not disconnect any part of a compressor if the system is under pressure. To avoid serious accidents, the following precautions should be taken before working on, or removing, any part of a compressor:

a. Leave all pressure gages open.

b. Be sure the compressor is actually secured and cannot be started automatically or accidentally.

c. Be sure the compressor is completely blown down.

d. Be sure all valves, including the control or unloading valves, between the compressor and the receiver are closed.

9. Operate a compressor at recommended speeds and maintain proper cooling water circulation to prevent damage from excessive temperatures.

10. Drain the circulating water system of a compressor if it is to remain idle for an extended period, or if it is to be exposed to freezing temperature.

AUXILIARY BOILERS

Information about the operation, maintenance, and safety regarding auxiliary boilers in this chapter supplements that given in *Engineman 3 & 2,* NAVEDTRA 10541 (current edition). Detailed information on construction, operation, and maintenance of auxiliary boilers must be obtained from the manufacturer's technical manual.

OPERATION

The operation of auxiliary boilers used on diesel-driven ships is under the supervision of an ENC or EN1. You should ensure that personnel charged with the operation and maintenance of an auxiliary boiler are thoroughly familiar with the boiler and its associated equipment. Satisfactory operation of the boiler depends on proper care and maintenance. Specific attention must be paid to maintaining automatic regulating, control, and safety devices in proper operating condition. Failure of these devices may lead to a major casualty, damage to equipment, and injury to personnel; therefore, continuous, alert watchstanding should be maintained while the auxiliary boiler is in semiautomatic or manual operation. An operating auxiliary boiler should never be left unattended.

TROUBLESHOOTING

Faulty operation of auxiliary boilers is indicated by various symptoms. These symptoms may indicate one or more conditions in the boiler. Each condition must be corrected. Consult the manufacturer's technical manual for detailed information on troubleshooting a particular boiler. Knowing the probable causes of a particular symptom can assist you in correcting any trouble quickly and efficiently. Some of the troubles encountered in the operation of auxiliary boilers and their causes are listed in figure 7-2.

AUXILIARY BOILER WATER TREATMENT

The auxiliary boiler feedwater is exposed to the same contaminants as the propulsion boiler feedwater. Auxiliary boilers are generally used for hotel service loads, and shore water used for feedwater is usually the prime source of contamination. The shore water may contaminate the feedwater system by leakage through malfunctioning galley mixing valves, laundry equipment, and

Symptom or Difficulty	Condition may be due to
Ignition failure	Faulty transformer. Broken or grounded high tension leads. Cracked high tension electrode insulator. Carbon deposits on electrodes or insulators. Incorrect electrode setting. Malfunctioning programing control cams. Faulty ignition cable connector. Solenoid oil or air valve fails to open. Water in the oil. Dirty or clogged burner tip.
Flame failure	Dirty glass in the photocell. Abnormal ambient temperature. Bad electron tube in the photocell. Damaged photocell. Faulty electron tube in the combustion safeguard control. Loose connection on the photocell. Out of oil or have water in the oil. Clogged fuel oil nozzle. Clogged fuel oil line or strainer. Broken pressure regulator spring. Faulty solenoid valve. Broken belt (V-belt drive).
Burner smokes or pulsates	Dirty nozzle. Excessive return line oil pressure (return flow system). Nozzle not positioned correctly. Insufficient air for combustion. Low oil pressure. Incorrect burner linkage setting. Incorrect setting of primary air. Low voltage (d-c machinery). Fluctuating voltage.
Oil pump fails to deliver	Leak in the suction line. Insufficient fuel in the tank. Clogged or dirty strainers. Worn pump members.

Symptom or Difficulty	Condition may be due to
Oil pump fails to deliver (continued)	Improper oil relief valve setting. Defective gasket on the oil pump. Leaky pump seal.
Blower fails to deliver	Slipping V-belts. Driver pulley loose on the shaft. Misalignment. Dirty fan blades. Restriction at the blower inlet. Seized bearings in the blower or the blower drive. Bent or broken shaft. Dirty air inlet screen. Insufficient supply voltage to motor (d-c machinery). Fluctuating voltage.
Feed pump fails to deliver	Dirty suction strainer. Abnormally high water temperature. Leak in the suction line. Pump packing gland leaks badly. Plugged inlet piping. Excessive discharge head. Slipping or broken drive coupling. Jammed pump impeller. Dirty water level relay contacts (electrode - probe type control). Malfunctioning pump time delay relay. Grounded water probes (electrode - probe type control). Pump vapor locked. Insufficient water supply. Reversed rotation. Wornout impeller. Defective water pressure gage.
Excessive vibration	Combustion pulses. Loose hold-dorn bolts. Badly worn bearings. Insufficient air to the burner. Loose mechanical fastings. Misalignment of rotating auxiliaries. Dynamic unbalance of rotating auxiliaries.

Figure 7-2.—Troubleshooting guide—auxiliary boilers. 121.21

hot water heaters. Shore water is usually hard water which contains high concentrations of dissolved solids and silica. Although it can have either high or low pH, in a boiler, shore water usually causes high pH. High concentrations of dissolved solids lead to boiler water carryover with the steam. Silica may be deposited on the boiler watersides and in the steam system as it vaporizes.

Water hardness leads to excessive usage of boiler water treatment chemicals which causes corrosion, scale, and sludge buildup. Excessively high pH causes caustic embrittlement and subsequent erosion of boiler metal parts.

Firetube and watertube auxiliary boilers are natural circulation boilers. The water treatment for natural circulation auxiliary boilers is maintained in the same manner as the propulsion boiler water. Section 21 of *Naval Ships' Technical Manual*, chapter 220, volume 2, describes this water treatment. The control parameters for auxiliary boiler water are alkalinity, phosphate, and chloride. In auxiliary boilers, the alkalinity of the auxiliary boiler water is measured instead of the pH because its higher alkalinity level can be more easily measured by the alkalinity test than by the pH meter test. The alkalinity range is equivalent to a pH range of 11.0 to 11.3. The auxiliary boiler limits are given in table 7-1.

The same treatment chemicals, trisodium phosphate dodecahydrate (TSP) and disodium phosphate anhydrous (DSP), are used for auxiliary boiler water treatment except that a higher level must be maintained due to the lower operating pressures. The TSP provides alkalinity and phosphate. The DSP provides additional phosphate without significantly affecting the alkalinity.

Table 7-1.—Auxiliary Boiler Water Limits For Firetube and Natural Circulation Water Tube Auxiliary Boilers

Alkalinity:	1.0 - 2.0 epm (1.0 - 2.0 meq/L)
Phosphate:	200 - 400 ppm (200 - 400 mg/L)
Chloride:	10.0 epm (10.0 meq/L) maximum

Initial Treatment

The boiler is initially half-filled with feedwater to partially dilute the treatment chemicals which must be added. The treatment chemicals are then added to bring the boiler water conditions to near the upper limits. The necessary amounts of treatment chemicals are weighed, dissolved in feedwater, and injected into the boiler.

WARNING: TSP solutions are corrosive and cause burns to skin, eyes, and body tissues. Affected personnel should flush skin with cold water. If TSP or its solutions enter the eyes, flush with cold water and obtain immediate medical attention.

TSP is added to bring the alkalinity to 2.0 equivalents per million (epm) (2.0 meq/L) and to provide some of the needed phosphate. DSP is added to bring the phosphate to 300 parts per million (ppm) (300 mg/L) and not to the upper limit of 400 ppm (400 mg/L). In order to determine the amount of chemicals needed, the volume of water requiring chemical treatment must be known. This information is sometimes available in the instruction manual for the boiler. If the weight of water at normal steaming level while steaming is given, divide the weight in pounds by 8.33 to determine volume in gallons. If the boiler weight data gives only the dry weight and the wet weight of the boiler, determine the boiler water chemical treatment volume as follows:

1. Subtract the boiler dry weight from the boiler wet weight to obtain a weight of cold water in the boiler.
2. Divide the weight of cold boiler water in pounds by 9.30 for boilers operating at 125 pounds per square inch (psi) or 8.87 for boilers operating at 35 psi to obtain the boiler water volume, in gallons, for chemical treatment. This volume times the initial chemical treatment factors (ounces per gallon) given in table 7-2 determines the ounces of TSP and DSP required. Enter the volume to the nearest gallon and the calculated dosage to the nearest one-half ounce in the appropriate columns.

Table 7-2.—Natural Circulation Auxiliary Boiler Water Initial Dosage

	Factor (ounces/ gallon)	X	Boiler Volume for Chemical Treatment (gallons)	=	Initial Dosage (ounces)
TSP	0.100	x	____________	=	____________
DSP	0.022	x	____________	=	____________

Initial dosages for several of the auxiliary boilers are given in table 7-3. The volumes listed are for the following vessels:

FF-1040, FF-1041, AGFF-1	215 gallons
Other ships having pressure-fired main boilers	300 gallons
LST- 1179 class	280 gallons
MSOs having cyclotherm MC-800 boilers	84 gallons

Weigh the necessary amount of chemicals and place both in the 10-liter safety dispensing bottle. The safety dispensing bottle should be marked and used "For boiler water treatment chemicals only." Add cold feedwater, cap the bottle and spout, then shake to dissolve. Inject the solution into the boiler.

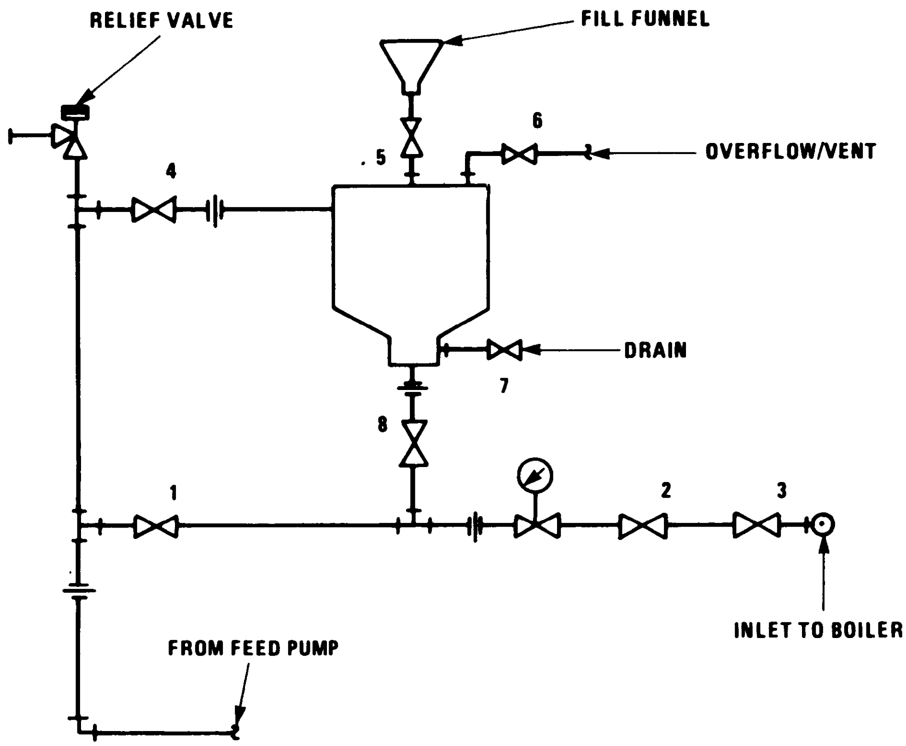
Auxiliary boilers are equipped with a chemical injection system on a bypass of the feedwater line. One treatment system schematic and general procedures for auxiliary boilers are presented in figure 7-3. When you are operating an injection system, slightly overfill the tank to bleed air out of it. The over-filling must be minimal; otherwise an excessive amount of treatment will be discharged to the bilge. In addition, injection must continue for at least 10 minutes to ensure that all of the treatment is flushed into the boiler. Upon completion of the chemical addition, finish filling the boiler to the lightoff level, or if the boiler has been overfilled, drain until the proper water level is reached. A boiler water sample obtained from a

Table 7-3.—Chemical Weights For Freshly Filling Some Auxiliary Boilers

Boiler Water Volume for Chemical Treatment (gallons)	84	215	280	300
Weight required *TSP (ounces)	8.5	21.5	28	30
Weight required **DSP (ounces)	2	4.5	6	6.5

1 gallon = 3.785 liters
1 ounce = 28.35 grams
16 ounces = 1 pound

*TSP - Trisodium Phosphate
**DSP - Disodium Phosphate



WARNING: Protective clothing shall be worn while pouring concentrated chemicals into chemical injection tank and while topping off.

GENERAL PROCEDURE FOR ADDING CHEMICAL (ASSUMING VALVES SET FOR NORMAL OPERATION, i.e., VALVES 1,2,3 OPEN AND VALVES 4,5,6,7,8 CLOSED).

1. **Slowly open valves 7 (drain), 6 (overflow/vent), and then 5 (funnel fill).**
2. **Close valve 7.**
3. **Charge the injection tank with treatment chemicals already in solution through the funnel.**
4. **Top off tank with feedwater obtained in bucket until an overflow just starts.**
5. **Close valves 5 and 6.**
6. **Open valves 4 and 8.**
7. **Close valve 1.**
8. **Maintain a flow of water for 10 minutes to wash out the injection tank.**

INJECTION TANK SECURING PROCEDURE

1. **Open valve 1.**
2. **Close valves 4 and 8.**
3. **Drain injection tank by first slowly opening valve 7 and then valve 6.**
4. **Close valves 6 and 7.**

121.54

Figure 7-3.—Auxiliary Boiler Chemical Injection Procedure.

freshly filled, chemically treated boiler, prior to light off, is not representative and is therefore meaningless. The freshly filled and treated boiler shall be steamed immediately but not later than 24 hours after being filled. Preferably, the boiler should not be filled unless it is expected to be fired within 24 hours. If the boiler cannot be steamed within 24 hours, it should be placed under dry layup in accordance with chapter 221, Boilers, *Naval Ships' Technical Manual.*

ALKALINITY AND PHOSPHATE.—Since the addition of TSP to raise the alkalinity also raises the phosphate, the control of alkalinity and phosphate are linked. The DSP provides additional phosphate as needed. The boiler water volume for chemical treatment must be determined as described earlier. Using this volume, the dosages of TSP and DSP are calculated. Table 7-4 gives the TSP dosage factor (ounces per gallon) for all values of alkalinity. The boiler volume is multiplied by the factor and the dosage of TSP is entered to the nearest one-half ounce in the appropriate space. The increase in phosphate due to TSP is given in the last column. The DSP dosages are calculated similarly using the DSP factors (ounces per gallon) given in table 7-5. TSP and DSP dosages for the auxiliary boilers are given in tables 7-6 and 7-7. The procedures for determining the chemical treatment

Table 7-4.—Trisodium Phosphate Dosage For Natural Circulation Auxiliary Boilers (Trisodium Pbosphate, Dodecahydrate, $Na_3PO_412H_20$)

Boiler water Alkalinity epm (meg/L)	TSP Dosage Factor (ounces/gallon)	X	(Enter) Boiler Water Volume for Chemical Treatment (gallons)	=	(Calculate) Ounces of TSP required to raise alkalinity to 2.0 epm	Phosphate Correction
0.1	0.095	X		=		180
0.2	0.090	X		=		170
0.3	0.085	X		=		160
0.4	0.080	X		=		150
0.5	0.075	X		=		140
0.6	0.070	X		=		130
0.7	0.065	X		=		120
0.8	0.060	X		=		110
0.9	0.055	X		=		100
1.0	0.050	X		=		90
1.1	0.045	X		=		90
1.2	0.040	X		=		80
1.3	0.035	X		=		70
1.4	0.030	X		=		60
1.5	0.025	X		=		50
1.6	0.020	X		=		40
1.7	0.015	X		=		30
1.8	0.010	X		=		20
1.9	0.005	X		=		10

1 gallon = 3.785 liters
1 ounce = 28.35 grams

TSP - Trisodium Phosphate

Table 7-5.—Disodium Phosphate Dosage For Natural Circulation Auxiliary Boilers (Disodium Phoshate, Anhydrous Na_2HPO_4)

Corrected Boiler Water Phoshate ppm (mg/L)	DSP Dosage Factor (ounces/gallons)	X	(Enter) Boiler Water Volume for Chemical Treatment (gallons)	=	(Calculate) ounces of DSP Required to raise Phosphate to 300 ppm (300 mg/L)
10	0.058	X		=	
20	0.056	X		=	
30	0.054	X		=	
40	0.052	X		=	
50	0.050	X		=	
60	0.048	X		=	
70	0.046	X		=	
80	0.044	X		=	
90	0.042	X		=	
100	0.040	X		=	
110	0.038	X		=	
120	0.036	X		=	
130	0.034	X		=	
140	0.032	X		=	
150	0.030	X		=	
160	0.028	X		=	
170	0.026	X		=	
180	0.024	X		=	
190	0.022	X		=	
200	0.020	X		=	
210	0.018	X		=	
220	0.016	X		=	
230	0.014	X		=	
240	0.012	X		=	
250	0.010	X		=	
260	0.008	X		=	
270	0.006	X		=	
280	0.004	X		=	
290	0.002	X		=	

1 ounce - 28.35 grams
1 gallon - 3.785 liters

DSP - Disodium Phosphate

dosages for the completed dosage tables are described below:

1. Determine the alkalinity and phosphate concentrations in the boiler water from sample results.

2. Locate the boiler water alkalinity in the first column of table 7-4. Then read across to the weight of TSP required for the correct volume. (Use table 7-6 for the vessels listed earlier in the chapter.) Enter this weight in the log.

Table 7-6.—Calculated Trisodium Phosphate Dosages For Some Natural Circulation Auxiliary Boilers (Trisodium Phosphate, Dodecahydrate $Na_3Po_412H_2O$)

Boiler Water Alkalinity epm (meg/L)	Boiler Water Volume at Normal Steaming Level (Gallons)				Add to Current Phosphate
	84	215	280	300	
	Ounces of TSP Required to Raise Alkalinity to 2.0 epm (2.0 meq/L)				
0.1	8	20.5	26.5	28.5	180
0.2	7.5	19.5	25	21	170
0.3	7	18.5	24	25.5	160
0.4	6.5	17	22.5	24	150
0.5	6.5	16	21	22.5	140
0.6	6	15	19.5	21	130
0.7	5.5	14	18	19.5	120
0.8	5	13	17	18	110
0.9	4.5	12	15.5	16.5	100
1.0	4	10.5	14	15	90
1.1	4	9.5	12.5	13.5	90
1.2	3.5	8.5	11	12	80
1.3	3	7.5	10	10.5	70
1.4	2.5	6.5	8.5	9	60
1.5	2	5.5	7	7.5	50
1.6	1.5	4.5	5.5	6	40
1.7	1.5	3	4	4.5	30
1.8	1	2	3	3	20
1.9	0.5	1	1.5	1.5	10

1 ounce = 28.35 grams
1 gallon = 3.785 liters

TSP - Trisodium Phosphate

3. Continue to the last column to find the phosphate correction. This is the amount the phosphate will increase due to the TSP. Record the phosphate correction in the log.

4. Add the phosphate correction caused by TSP to the measured boiler water phosphate. This gives the corrected phosphate concentration; record this in the log.

5. Proceed to table 7-5. Locate the corrected phosphate in the first column. Read across the table to the weight of DSP required for the correct volume. (Use table 7-7 for the vessels listed earlier.) Enter this weight in the log.

6. Weigh the chemicals, dissolve them together in the 10-liter safety dispensing bottle, and inject the solution into the boiler.

NOTE: TSP must be dissolved in cold feedwater since TSP generates heat when dissolving. DSP must be dissolved in hot feedwater if only DSP will be injected into the boiler. Therefore, TSP should be added first to cold water in the bottle, then dissolved. This will generate sufficient

Table 7-7.—Calculated Disodium Phosphate Dosages For Some Natural Circulation Auxiliary Boilers, (Disodium Phosphate Anhydrous, Na_2HPO_4)

Corrected Boiler Water Phosphate ppm (mg/L)	Boiler Water Volume at Normal Steaming Level (Gallons)			
	84	215	280	300
	Ounces of DSP Required to Raise Phosphate to 300 ppm (300 mg/L)			
10	5	12.5	16	17.5
20	4.5	12	15.5	17
30	4.5	11.5	15	16
40	4.5	11	14.5	15.5
50	4	10.5	14	15
60	4	10	13.5	14.5
70	4	10	13	14
80	3.5	9.5	12.5	13
90	3.5	9	12	12.5
100	3.5	8.5	11	12
110	3	8	10.5	11.5
120	3	7.5	10	11
130	3	7	9.5	10
140	2.5	7	9	9.5
150	2.5	6.5	8.5	9
160	2.5	6	8	8.5
170	2	5.5	7.5	8
180	2	5	7	7
190	2	4.5	6	6.5
200	1.5	4.5	5.5	6
210	1.5	4	5	5.5
220	1.5	3.5	4.5	5
230	1	3	4	4
240	1	2.5	3.5	3.5
250	1	2	3	3
240	0.5	1.5	2	2.5
270	0.5	1	1.5	2
280	0.5	1	1	1
290	0.5	0.5	0.5	0.5

1 gallon - 3.785 liters
1 ounce - 28.35 grams

DSP - Disodium Phosphate

heat to dissolve the DSP when it is transferred to the TSP solution.

Remember, treatment in accordance with the DSP dosage table will not bring the phosphate level to the upper limit of 400 ppm (400 mg/L) but will only raise it to 300 ppm (300 mg/L). DSP is added to allow a margin for phosphate in case it should become necessary to treat the feedwater only for alkalinity since the addition of TSP to raise alkalinity will also increase its phosphate level. The boiler must never be surface blown if this action will cause boiler water limits to go below the minimum requirements for alkalinity and phosphate, regardless of the chloride level. A 10 percent blowdown will cause the phosphate, alkalinity, and chloride levels to drop by 10 percent. There are no “dump” limits for alkalinity or phosphate. From the standpoint of feedwater consumption, it is better to secure and dump the boiler when its alkalinity level is 6 epm (6 meg/L) or when its phosphate level is 1200 ppm (1200 mg/L).

CHLORIDE.—If feedwater quality is properly maintained, a maximum concentration of 10.0 epm (10 meg/L) chloride in boiler water can be achieved without difficulty. Leakage of seawater into the feedwater system, or abnormally high makeup rates, will cause a continuous increase in the chloride level of boiler water. Boiler water chloride level is controlled by surface blowdown and by elimination of seawater contamination in the feedwater. If a serious seawater contamination situation arises, every effort must be made to isolate and correct the source of contamination and to limit it to the system already contaminated. If the boiler water chloride level exceeds 30 epm (30 meg/L), more makeup feed is needed to conduct surface blowdowns than is used in dumping, flushing, and refilling the boiler.

For additional information about boiler water/feedwater test and treatment, read chapter 220, volume *2,* of the *Naval Ships' Technical Manual.* This manual covers such subjects as (1) steam plant water chemistry principles, (2) water requirements for propulsion boilers, (3) casualty control, (4) quantitative analysis and troubleshooting, (5) chemical safety precautions, (6) supply information, and (7) water requirements for auxiliary boilers.

HYDRAULIC SYSTEMS

The overall efficiency of the hydraulic installations used to control or drive auxiliary machines is basically dependent upon the size, oil pressure, speed, and stroke of the hydraulic installation. The efficiency of the hydraulic speed gears and the components of the system as a whole will depend upon the care which is given them. Since major repair of hydraulic gear, except for piping and fittings, is generally done in a naval shipyard or by the manufacturers, this section will deal primarily with troubleshooting and preventive maintenance.

Hydraulic transmissions are sturdy, service-proven machines, inspected and tested with such care that casualties seldom occur except as a result of faulty assembly, installation, or maintenance. A correctly installed hydraulic system, operated regularly and serviced with proper care, will retain its design characteristics of power, speed, and control. The need for costly repair and replacement will seldom occur if the equipment has been maintained properly.

TROUBLESHOOTING

Troubleshooting an electrohydraulic system involves the systematic elimination of the possible causes, one by one, until the actual cause of a casualty is found. In attempting to locate the source of any trouble in an electrohydraulic system, remember that all troubles occur in one of three categories—hydraulic, electric, or mechanical. Isolating a trouble into one of these categories is one of the main steps in locating the source of trouble.

Hydraulic Troubles

Casualties in a hydraulic system 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 you are certain that the trouble exists within that unit. Unnecessary disassembly may create conditions which lead to additional trouble, since dirt may enter an open system.

Leaks are a frequent cause of trouble in hydraulic equipment. Generally, leaks are a result of excessively worn parts, abnormal and continuous vibration, excessively high operating pressures, or 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 seating squarely.

Internal leaks usually result in unsatisfactory operation of the equipment. Large internal leaks are signified by loss of pressure and failure of equipment. While large internal leaks can usually be located by installing pressure gages 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 improperly fitted or damaged gaskets.

The symptoms of trouble in a hydraulic system are frequently 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 a specific trouble can be learned only through practical experience, the following descriptive terms will give a general idea of the noises which are trouble warnings.

If POPPING and SPUTTERING noises occur, 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 transmission lines. When this occurs, check for improper venting. Sometimes, a POUNDING or RATTLING noise occurs as the 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 ignored if it stops when speed or load is reduced. If the noise persists at low speeds or light loads, the system needs to be vented of air. Air in a hydraulic system can also cause uneven motion of the hydraulic motors.

When a GRINDING noise occurs, it can usually be traced to 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 lines, or by binding of some part of the equipment.

SQUEALS or SQUEAKS indicate that the packing is too tight around some moving part or that a high-frequency vibration is occurring in a relief valve.

Electrical Troubles

Even though troubles occurring in electrical equipment are the responsibility of the Electrician's Mate, the Engineman can facilitate maintenance of such equipment by making a few simple checks when electrical troubles occur. Failure to have a switch in the ON position will cause unnecessary delay in operating electrical equipment. If the switch is closed and the equipment still fails to operate, check for blown fuses and tripped circuit breakers. Troubles of this type are usually the result of an overload on the equipment. If a circuit breaker continues to cut out, the trouble may be caused by damaged equipment, excessive binding in the electric motor, obstruction in the hydraulic transmission lines, or faulty operation of the circuit breaker. Check for visual indication of open or shorted leads, faulty switches, and loose connections. Do not make repairs to the electrical equipment or system and do not open enclosures of electrical equipment, but report the condition to the Electrician's Mate when evidence of electrical failure is found.

Mechanical Troubles

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 according to the manufacturer's instructions for the specific piece of equipment.

MAINTENANCE

The principal requirements necessary to keep a hydraulic transmission in satisfactory operating condition are regular operation, proper lubrication, and the maintenance of all the units and the fluid in the required state of cleanliness. Regular operation of hydraulic equipment prevents the accumulation of sludge and the freezing of adjacent parts, and aids in preventing corrosion. The necessity of proper lubrication and cleanliness cannot be too strongly emphasized.

Detailed instructions on the maintenance of a specific unit should be obtained from the appropriate manufacturer's technical manual, but the following general information will also be useful.

The Fluid System

If an inspection of an oil sample drawn from a hydraulic system reveals evidence of water, sludge, or acidity, the system must be DRAINED, then CLEANED with the prescribed acid-free cleaning fluid (flushing oil), and FILLED with clean hydraulic oil. A hydraulic system may be drained and cleaned as follows:

1. Remove permanent filters and wash them in flushing oil. Then use low pressure air for drying purposes. If filters have replaceable elements, install new elements.
2. Drain the system of old hydraulic oil as completely as possible.
3. Close all connections and fill the system with acid-free cleaning fluid.
4. Start and operate the unit under idling conditions in order to fill the system thoroughly with the cleaning fluid.
5. Secure the unit and allow it to stand idle for the prescribed period (usually about an hour). This period of idleness permits the cleaning fluid to dissolve any sludge.
6. Start and operate the unit with a light load for a short interval of time (3 to 5 minutes, unless otherwise specified). Allow the equipment to stand idle for about 15 minutes, then repeat the whole cleaning process. Do this two or three times.

Never operate a hydraulic unit with a full load when it is filled with cleaning fluid. Keep the operating pressure as low as possible.

After each short operating period, turn the cleaning handles of edge type filters (if installed) and drain from the filter an amount of cleaning fluid equal to its volume.

7. If time permits, allow the system to stand idle for an additional hour following the series of short operating periods.
8. Drain the system of cleaning fluid. Reclean permanent filters, if necessary; install new replaceable filters. Close the system, and fill it with the proper hydraulic oil.

As the system is filled, the hydraulic oil should be strained through a fine wire screen of 180 or 200 mesh. If oil is not clean, it should be run through a centrifuge. Adequate protection should be provided against dust and moisture. Moisture should be expelled from the oil before it is poured into a system; oil with noticeable water content should be rejected or centrifuged.

When a hydraulic system is being filled, sufficient hydraulic fluid should be used to completely fill the active parts of the mechanism, leaving no air pockets. Air valves should be opened during the filling process, so that air can escape to the oil expansion box. Be sure the valves are closed tightly after the system has been filled.

Pumps and Motors

Whether the pumps and motors of hydraulic transmissions are of the axial or radial piston type, the maintenance procedures, as well as the operating principles, are relatively the same. In general, maintenance information on other types of pumps also applies to hydraulic pumps and motors.

Neoprene is utilized as a seal around the shafts of most modern hydraulic pumps and motors, but other types of shaft packing are also used.

On some modern hydraulic transmissions, the SHAFT STUFFING BOX PACKING is of the square-braided pure asbestos type. This packing is easily removed, but care must be taken to ensure that it is not replaced too tightly. If properly installed, this packing makes a tight joint when you apply light pressure. If packing wears out quickly, the shaft should be inspected for roughness. If a lathe is available, roughness may be eliminated from a shaft by a finishing cut to smooth the surface. If a lathe is not available, it may be necessary to replace the shaft. Packing should be renewed at prescribed intervals to eliminate the possibility of the packing becoming hard and scoring the shaft. When packing is being replaced, make certain that there is a uniform thickness around the shaft. An excess of packing on one side of the shaft will cause shaft deflection and may cause breakage. Stuffing boxes should be packed loosely and the packing gland set up lightly to allow adequate leakage for cooling and lubrication.

There will be very little 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 connecting units are installed. However, when a casualty occurs or a unit is replaced, it is possible for units to get out of alignment sufficiently to cause severe stress and strain on the coupling and connected parts. Excessive misalignment should be eliminated as soon as possible by replacing any defective parts and by readjusting the aligning devices. If this is not done, pins, bushings, and bearings will wear out too fast and will have to be replaced frequently.

Since there is no end play to either the pump shaft or the 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.

Piping and Fittings

If properly installed, the piping and valves of a hydraulic system are seldom a source of trouble, except for leakage. Since some leaks, however, can be of sufficient seriousness to cause a reduction in the efficiency of the unit, frequent inspections should be made for leakage and steps should be taken to eliminate any leakage found.

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 auxiliary gear while the leaking flange is being refitted with copper asbestos or "O" ring packing. Be sure the flange surfaces are cleaned carefully before the packing is applied.

CAUTION: Exposure to asbestos fibers is a recognized health hazard. Refer to N.S.T.M. chapter 635 for safety requirements applicable to handling asbestos packing and gaskets.

Operation of hydraulic equipment may be continued while leakage repairs are being made in some parts of the system if certain measures are taken. When lines in an auxiliary system leak, they should be valved off from the main line connection to prevent leakage between the two systems. If leaks occur in the pumping connections to the three-way valves of a steering gear installation, the pump can be cut out with the valve, and another pump cut in. If the three-way valves fail to cut out the leaking unit, and it becomes necessary to cut out both pumps of a steering gear installation, the valves may be closed at the ram cylinder. Since hydraulic systems will work without pressure control, leaking pipes or cylinders of the pressure control can be cut out of the system for repair by closing the valves in the lines where they join the main piping.

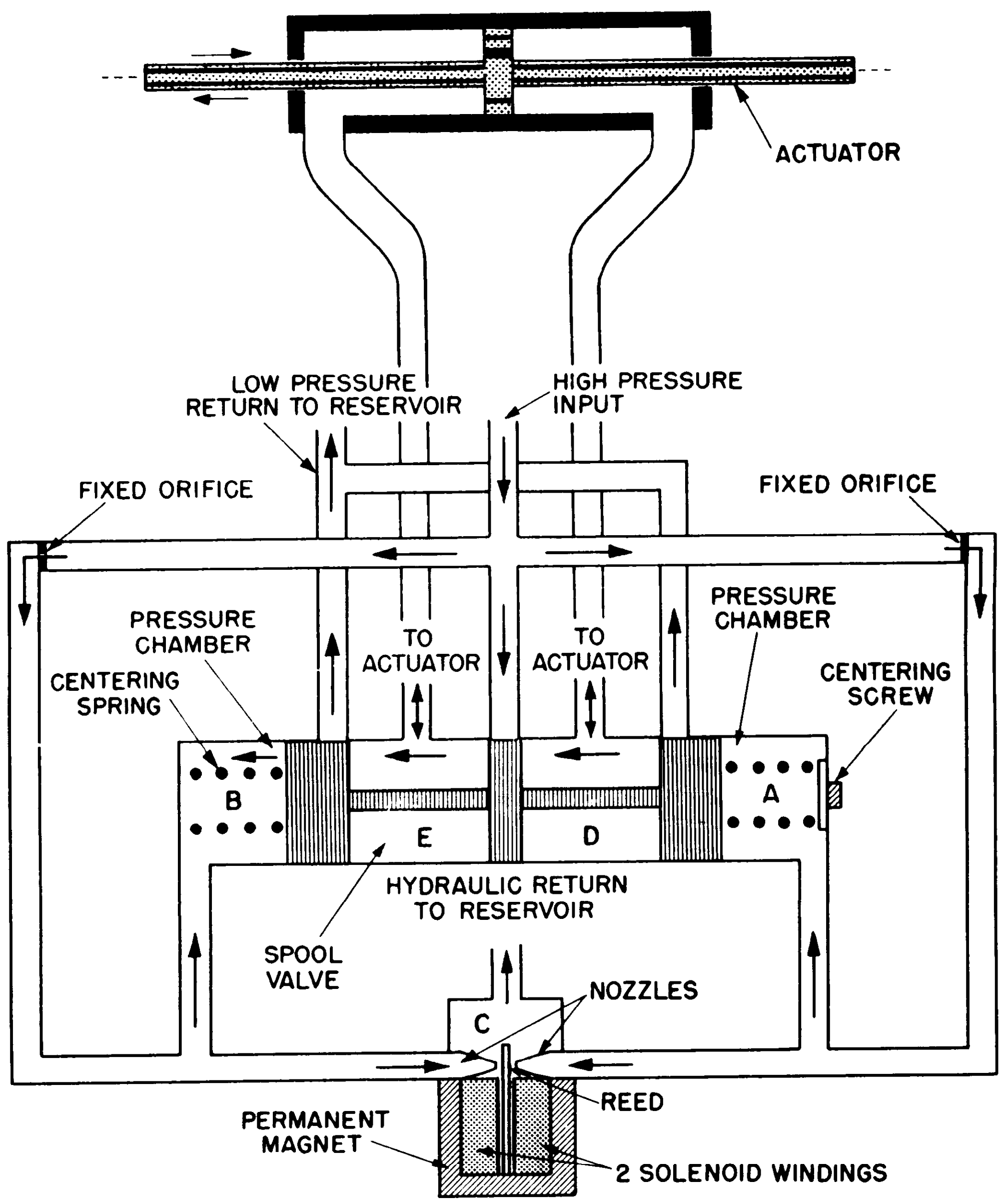
Expansion lines and replenishment lines in hydraulic systems of older ships are seldom a source of leakage or breakage, since they are not under any appreciable pressure; however, all connections must be maintained intact. In more recent installations, however, replenishing lines are under pressure of as much as 300 psi. In these installations, the hydraulic systems should not be operated during repair of the lines.

Relief valves and shuttle valves of a hydraulic system may also be a source of trouble. The seats of relief valves which are leaking should be reground. Loss of power is a symptom of a leaking relief valve. Shuttle valves may stick and fail to cut off; this condition is evidenced either by the escape of oil from the high pressure side of the line into the expansion tank or by the failure of the pressure control. When a shuttle valve fails to operate, the stop valves should be closed and the defective valve removed and repaired.

Incorrectly adjusted needle valves can be another source of trouble. Needle valves which are adjusted too fine may cause the device operated by the valve to stop short of its intended stopping point. This may happen because the valve adjustment may allow more fluid to pass through leakage points in the system than through the valve.

SERVOVALVES

Although there are many types of valves used for control in a hydraulic system, the valve



33.185(33A)

Figure 7-4.—Servovalve—neutral.

most commonly used when fine control is desired is the servovalve (servocontrol). Servocontrol may be defined as a control actuated by a feedback system which compares the output signal with the input or reference signal and makes corrections to reduce the differences. The feedback signal may be provided by fluid pressure, mechanical linkage, electrical signal, or a combination of the three.

One type of hydraulic servovalve is illustrated in figure 7-4. The valve is controlled by two solenoids through an amplifier which energizes either the right or left solenoid, depending on the input signal. The valve shown in figure 7-5 has the right solenoid energized; this causes the reed to block the right nozzle and causes a pressure increase in chamber A. The increased pressure causes the spool valve to start sliding to the left. As the spool valve moves, it uncovers the high pressure line to chamber D (right side of the piston) and the return line from the left side of the piston through chamber E (nonpressure side of the hydraulic system). The synchromotor is geared to the actuator shaft. As the actuator moves to the left, the synchromotor rotates and produces a feedback signal to the amplifier. When the feedback signal and the input signal are matched, the solenoid is deenergized and the magnetic reed returns to the neutral position. With

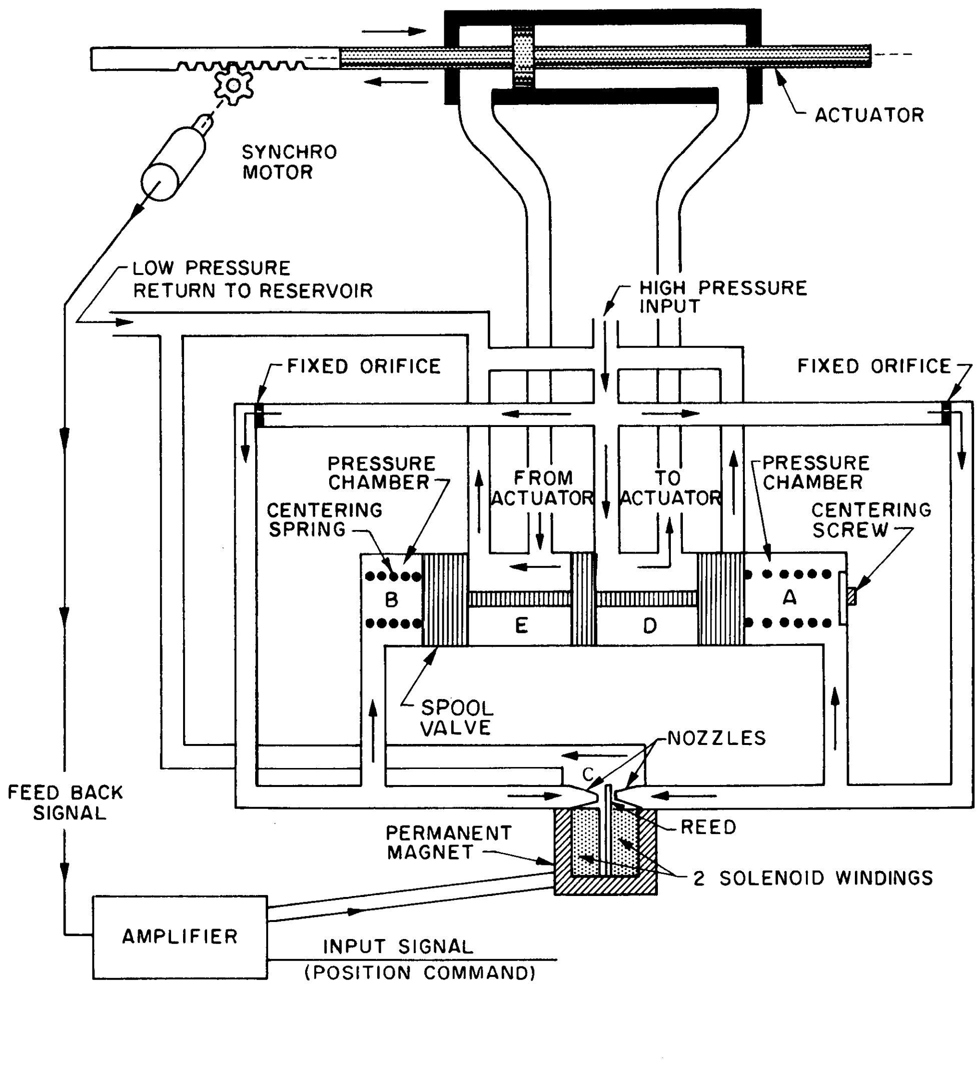


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Figure 7-5.—Servovalve—actuated.

the reed in the neutral position, the fluid pressure is relieved to chamber C through the nozzles and a pressure drop allows the centering springs to return the spool valve to a central position; in this position, the valve blocks the pressure and return line, creating a hydraulic lock in chambers E and D. By energizing the left-hand solenoid, the magnetic reed will move to the left and the entire process will be reversed.

The position of the spool valve can be adjusted by using the centering screw. Fixed orifices are used so that the pressure drop in the hydraulic servovalve will not create a pressure drop in the opposite nozzle which is closed. Note that the servovalve is basically a sliding spool valve. This type of valve has many other applications in hydraulic systems. For example, servovalves are used in the guidance systems of missiles and in the control systems of aircraft.

DISTILLING PLANTS

This section will deal with the operation, troubleshooting, and repairing of the submerged tube and the flash type distilling plants that are used by the Navy. For additional and more detailed information than is provided by this training manual, consult the manufacturer's technical manual for the type of distilling plant installed on your ship.

Distilling plants in naval ships are of three general types: (1) vapor compression, (2) low-pressure steam, and (3) heat recovery. The major differences between the three types are the kinds of energy used to operate the units and the pressure under which distillation takes place. Vapor compression units use electrical energy (for heaters and compressors). Low-pressure steam distilling units use low-pressure steam from either the auxiliary exhaust steam systems or the auxiliary steam system. Heat recovery distilling units use diesel engine jacket water instead of steam as the heat source. Vapor compression units boil the feedwater at a pressure slightly above atmospheric pressure. Low-pressure steam and heat recovery units depend on a relatively high vacuum for operation.

Vapor compression type distilling units are used in submarines and small diesel-driven surface craft where the daily requirements do not exceed 4000 gallons per day (gpd). Since the vapor compression type found on surface crafts is being replaced with the heat recovery distilling units, vapor compression distilling units will not be covered in this manual. Chapter 531 (9580-II) of *Naval Ships' Technical Manual* contains information on these plants.

The low-pressure steam distilling unit is used in all steam-driven surface ships and nuclear submarines. Enginemen usually share responsibility with Machinist's Mates for the maintenance and operation of the low-pressure steam distilling plants.

There are two reasons why low-pressure steam distilling units are considered "low pressure": (1) they use low-pressure steam as the source of energy, and (2) their operating shell pressure is less than atmospheric pressure.

The three major types of low-pressure steam distilling units are submerged tube, flash type, and vertical basket.

In this section of the chapter we will be discussing only two of these distilling units—the submerged tube and the flash type.

SUBMERGED TUBE PLANTS

Low pressure, submerged tube plants differ from ship to ship, but the 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 them ample opportunity to detect abnormal operating conditions before such conditions reach advanced stages. When operating troubles do occur, it is the responsibility of the EN1 or ENC on duty to locate the trouble and to make the necessary adjustments or repairs.

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.

During 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 in 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. 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. Following are the various factors which promote full output of the distilling plant. Any variations of these may cause a decrease in the plant's efficiency.

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.

(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 direction 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. Orifices should be inspected annually. An 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 and then the pressure reducing valve (if installed) should be checked to determine whether or not each valve is operating properly. If they are functioning properly and the pressure cannot be maintained above the orifice, you may assume that an insufficient amount of 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 because of the pressure drop through the reducing valve and orifice plate. A small amount of superheat has little or no effect on the operation or the scale formation; however, when live steam must be used, 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 freshwater 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. With increased salinity of the distillate, the fluctuations may cause priming, as well as erratic water levels in the shells. These fluctuations may be eliminated by proper operation of automatic pressure regulators in the steam supply line.

First-Effect Tube Nest Vacuum

The range of the pressure maintained in the first-effect tube must be between 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 reduces scale formation to a minimum, enabling the plant to operate at full capacity.

A vacuum reduction which results from any factor other than deposits on tube surfaces should be corrected to 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. Any 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 cause losses of capacity and economy. Losses of vacuum and capacity may be due to air leaks from the atmosphere into the generating steam line (downstream from the orifice plate), from the first-effect tube nest front header, and from the first-effect tube nest drain piping. 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 low 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 either to scale deposits in the seawater 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, otherwise false water level indications will be given. 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 carryover 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 carrying over of saltwater particles with the freshwater vapor, otherwise 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 causes of operating difficulties. In 1958, a new compound was authorized for treatment of evaporator feedwater. 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 *Engineman 3 & 2*, NAVEDTRA 10541 (current edition).

Last-Effect Shell Vacuum

Most manuafacturers' 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 seawater is 85 °F, and that the vacuum should be higher when the seawater 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 seawater, and ineffective use of heat transfer surface in the distilling condenser.

Testing 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 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 Saltwater 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 are provided in the allowance repair parts and 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 to permit emergency repairs 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 Solo-shell 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 (stamped on the nameplate). 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, 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 either to increase the steam pressure or to provide suitable drainage by installing a trap or by using 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 being cleaned or repaired. However, some of the latest plants have only one set of air ejectors.

When it becomes necessary to clean air ejector nozzles, they should be cleaned with the special nozzle reamers furnished to each ship for this purpose. Sharp-edged tools should never be used for cleaning nozzles because the nozzle surfaces will be damaged and the efficiency of the air ejectors will be impaired.

Procedures 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.

Since the air ejector strainer is usually an integral part of the air ejector inlet, it should be inspected and cleaned in accordance with the PMS. When a new plant is first put into operation, the strainer may require cleaning once a day or even more frequently. Failure to keep the strainer clean will cause a reduced or fluctuating vacuum. When 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 are not caused by 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 the necessary repairs to the valve made, 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, in accordance with the PMS, to prevent accumulations of foreign matter from interfering with the proper operation of the plant.

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 saltwater 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 saltwater 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 freshwater 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 PLANTS

The flash type evaporator, like all distilling plants, removes salts and other impurities from raw seawater 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 saltwater heater. Flash evaporation takes place at temperatures as low as 104°F. In addition, no boiling occurs on heat transfer tube surfaces; as a result, the scale formation is greatly reduced and operation at maximum efficiency is prolonged.

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 feedwater is flashed to vapor in five evaporator stages at successively lower pressures.

Connections (or passages) that exist between the evaporator stages are the feedwater and its distillate loop seals, which permit the flow of feedwater and distillate from stage to stage while preserving the varying degrees of vacuum in each stage.

Condensers are mounted on top of each stage between the front and rear water boxes. Feedwater 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 the condenser. Each condenser has a pet cock for venting entrained air and noncondensable gases.

The evaporator stages become larger in the direction of reduced pressure. The feedwater 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 0.065 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. 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 feedwater flowing through the tubes.

Distillate flows into the shell space surrounding the tubes through an inlet near the feedwater 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 and on the feedwater inlet piping.

As the distillate leaves the cooler, it is pumped to storage tanks, provided the salinity does not exceed 0.065 epm per gallon. (If the salinity exceeds 0.065 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 0.065 epm per gallon .)

Pet cocks are located on each end of the cooler 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 feedwater line between the condenser of the first evaporator stage and the saltwater 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 closely together in the top steam outlet, reduce the velocity of the steam and let the steam condense on the outside of the heat transfer tubes.

Feedwater 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 and acquires the heat of condensation of the air ejector steam before leaving the preheater at the rear water box outlet.

A salinity cell is set to energize at 0.10 epm. It operates as a shutoff valve in the piping below the condensate outlet to dump high salinity water to the bilge or the drain tank. A 6-inch loop seal in the condensate line ensures that the salinity cell is submerged at all times.

A thermometer is located on the front of the preheater, and a pet cock for venting is located on the water box.

The SALT WATER HEATER is a gas or liquid heat exchanger designed to raise the feedwater temperature prior to its entrance into the flash chamber of the first evaporator stage. The saltwater heater is mounted on the operating end of the evaporator and extends the full width of the unit. Feedwater 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 feedwater inlet and outlet temperatures; a third, mounted on the heater shell, to measure the steam temperature surrounding the tubes; and a fourth, mounted on top of the heater shell, to measure the temperature of the desuperheating temperature in the steam side.

The steam supply to the saltwater heater flows from the auxiliary exhaust line, through the regulating valve (1-5 psig) and then through an orifice which provides, within limits, a uniform flow of steam. It then flows past the desuperheater nozzle, which reduces the 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. 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 the regulating valve.) The desuperheater atomizes the heater condensate in the low pressure steam side of the heater.

The function of the saltwater heater is to provide feedwater to the inlet of the first evaporator stage flash chamber. Since the amount of heat from the steam is constant, the feedwater flow through the heater must be adjusted according to the inlet temperature so that the feedwater 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 saltwater heater by a two-stage, vacuum-producing air ejector.

The precooler receives its coolant from the feedwater pumped into the distilling unit. The flow of coolant is through the heat transfer tubes, where it makes six passes, entering and leaving at the front end of the cooler.

Steam and noncondensables are drawn into the cooler at the top near the rear of the cooler. Impingement 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 the vacuum in the precooler which causes the flow of steam and noncondensables from the evaporator.

A thermometer is mounted on the feedwater inlet of the cooler.

Cooling water from the air ejector precooler flows into the AFTER-CONDENSER, which is 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. The after-condenser 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 four and five 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 saltwater heater and the first three evaporator stages and, since the noncondensables from stages four and five are directed back into stage three, the two-stage ejector actually handles all noncondensables within the unit.

The suction chamber of the first stage of the second ejector (first two-stage) 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 the saltwater heater leading to the air ejectors. These plates prevent the air ejectors from withdrawing any undue amount of steam from the evaporator along with the noncondensables.

The discharge of the first stage of the second ejector is flanged to the suction chamber of the third (second two-stage) 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 pounds per square inch gage (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 feedwater inlet piping, removes solid matter from seawater 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 is ready to be removed and cleaned.

An inlet and outlet angle-type RELIEF VALVE is flanged into the feedwater inlet between the feedwater pump and the air ejector precooler. The valve is set to open at 75 psig to prevent pressure buildup from an obstruction in the feedwater lines or accidental operation of the feedwater pump with the feedwater control valve closed.

Two FLOWRATORS are mounted on the unit to measure the amount of feedwater and cooling water pumped into the system. Since the amount of fluid to be measured in both cooling and feedwater lines is large, the flowrators are mounted in bypass piping arrangements, measuring a small portion of the actual main stream flow and 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 serve 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, saltwater 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 freshwater 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 never be overlooked.

An 8 to 10 psig, low pressure hydrostatic test should be applied to the entire system in accordance with the PMS, and at any other time when there is an indication that air leakage may exist. The saltwater 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 the operation and maintenance of pumps is found in *Engineman 3 & 2,* NAVEDTRA 10541 (current edition). However, for details of any specific pump, consult the manufacturer's technical manual.

SALTWATER LEAKAGE.—Saltwater to distillate or saltwater 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. These cells are located downstream from each tube bundle. Tube leaks usually result from damaged or corroded tubes or from improper expansion of tubes into the 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 *Naval Ships' Technical Manual.*

Cleaning Heat Exchangers

The tubes of the distillate cooler, the air ejector condenser, and the stage condensers operate with comparatively cool saltwater inside them and seldom require cleaning. The seawater in the saltwater heater, on the other hand, is at a higher temperature and its 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 7-6.

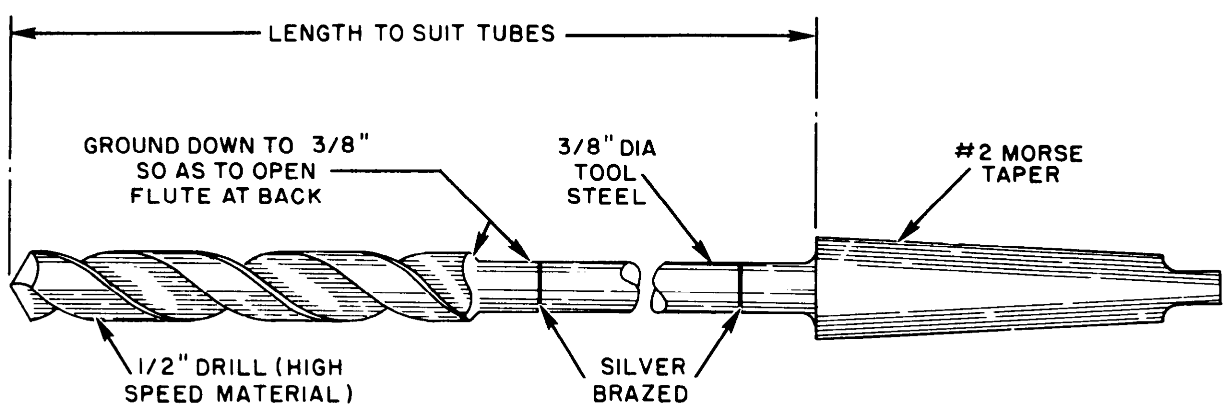

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Figure 7-6.—Tool for removing scale inside tubes.

The procedure for cleaning saltwater heaters is as follows:

1. Remove the waterheads.
2. 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.
3. 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 it is inserted into the tube.

An 8 to 10 psig hydrostatic test should be performed on the shell of the saltwater 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 saltwater 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.

AUTOMATIC PRESSURE CONTROL DEVICES

Most shipboard systems and machinery are protected by pressure or temperature control devices. Their maintenance and operation are the responsibility of the EN1 or ENC on duty. Of the various types of pressure and temperature control devices, the temperature control regulator, the relief valve, and the reducing valve are the types that you will encounter more often. Since temperature regulators were discussed in an earlier chapter, we will not cover them in this chapter. We will discuss only the relief valve and the reducing valve. Remember, the information given in this chapter is general. More detailed information can be obtained from the manufacturer's technical manual.

All reducing valves should be inspected, cleaned, and repaired semiannually, or whenever they do not operate properly.

RELIEF VALVES

Relief valves are designed to open automatically when the pressure in the line or the unit becomes too high. They are commonly installed in steam, water, and oil lines, and on various units of machinery where pressure must not exceed a certain limit. Relief valves prevent the building-up of an excessive pressure which may be caused by such conditions as the sudden closing of an outlet valve or the failure of a reducing valve.

There are many different types of relief valves, but most of them consist of a valve body containing a disk or ball. Under normal pressure conditions, the compression of a coil spring holds the disk or ball on its seat. When the pressure in a valve exceeds the resistance of the spring, the disk or ball lifts off its seat and the pressure is reduced until it falls below the pressure for which the valve is set.

Relief valves should be set at the lifting pressure specified by the manufacturer. The tension on the valve spring can be adjusted by means of an adjusting nut. The nut should be locked when the desired setting is attained. Since the setting for a specific valve will depend on the design of the valve and its use, the instructions in the applicable manufacturer's technical manual should be followed when any relief valve is being set.

Continual lifting (popping) of a relief valve indicates either excessive pressure or malfunctioning of the valve. Either condition should be corrected immediately. A relief valve which is not operating properly should be removed, disassembled, cleaned, and inspected. The disk, or ball, and the seat should be checked for pitting and excessive wear. The spring should be carefully inspected for possible defects. When a relief valve is removed for any reason, the spring tension must be reset.

Relief valves must never be locked in the closed position, except in an emergency. When emergency measures are taken, the valves must be repaired or replaced as soon as possible after the emergency.

REDUCING VALVES

Reducing valves are used to provide a steady discharge pressure lower than the supply pressure. They are used on gland seal lines, galley steam lines, heating system lines, and on many other reduced-pressure lines. A reducing valve can be set for any desired discharge pressure, within the limits of the design of the valve. After the valve is set, the reduced pressure will be maintained regardless of changes in the supply pressure, as long as the supply pressure is at least as high as the desired delivery pressure.

Two types of reducing valves are in common use, the spring-loaded reducing valve and the pneumatic pressure-controlled reducing valve. Reducing valves of the pneumatic type are of two designs—those which regulate low temperature fluids such as water or oil, and those which regulate high temperature fluids such as steam or hot water.

Spring-Loaded Reducing Valve

If a spring-loaded reducing valve fails to operate properly, the trouble may be due to one or more of the following causes:

1. The adjusting spring may have taken a permanent set. Readjust it or install a new spring.

2. The diaphragm may be damaged or excessively deformed. Install a new diaphragm or, if the deformation is slight, make a proper adjustment of the adjusting spring.

3. Leakage may be caused by failure of the main valve or the auxiliary valve to seat properly. Check the valves for wear and for the presence of dirt or scale. Correct the trouble by cleaning and grinding-in the main valve and the auxiliary valve. After grinding-in the auxiliary valve, the auxiliary valve stem may be too long. If it is too long, face off the end of the auxiliary valve stem until the proper clearance is obtained between the diaphragm and the end of the valve stem.

Pneumatic Pressure-Controlled Reducing Valve

The pneumatic pressure-controlled reducing valve has a water seal in the upper half of the dome and a glycerine seal in the lower half of the dome. The glycerine seal is put in at the factory; the water seal is put in when the valve is installed. The condensation of steam is sufficient to maintain the water seal at the proper level after the valve has been placed in service. When the valve is being repaired, however, the water seal will probably be lost. Be SURE to replace the water seal before putting the valve back in service, since steam must not be allowed to come in contact with the diaphragm. The glycerine seal does not, as a rule, require replacement in service. However, if it is necessary to replace or replenish the glycerine seal, place the dome in its normal vertical position and fill it with glycerine to the level of the filling plug. Screw the plug in and tighten it. In an emergency, water may be used temporarily, instead of glycerine, for the lower seal.

If a pneumatic pressure-controlled reducing valve fails to operate properly, check the following:

1. If the pressure in the lower dome becomes excessively high soon after the valve has been put into service, the extra pressure may be caused by expansion of the air due to temperature changes. Bleed enough air from the dome so as to maintain the proper pressure at the operating temperature.

2. If there is a gradual loss of pressure in the lower dome, check the bleeder valve, the air-loading connection, the pressure gage connection, and the filling plug for air leakage.

3. If the reduced pressure builds up beyond the set pressure, steam may be leaking past the valve. Check the valve for wear and for the presence of dirt or scale; also check to be sure that the valve stem is not binding and holding the valve open.

4. If the reducing valve closes and fails to deliver steam, check the dome pressure gage. If it reads the same as the outlet pressure gage, the diaphragm has probably failed.

The procedures to be followed when a reducing valve is being inspected, cleaned, and repaired will depend upon the design of the valve and its use. Therefore, the maintenance of a specific reducing valve should be accomplished in accordance with the instructions provided in the applicable manufacturer's technical manual.

CHAPTER 8

ENVIRONMENTAL POLLUTION

Several laws have been enacted in the past to control both air and water pollution, but, for various reasons, they were largely ineffective. With increased awareness, however, that our ecological system was seriously endangered by pollution, Congress on 1 January 1970 passed the National Environmental Policy Act of 1969, and followed in April with the Environmental Quality Improvement Act of 1970. In these two Acts Congress declared a national policy for enhancement of environmental quality and assigned responsibilities for carrying out this policy.

Briefly, these Acts require the Federal Government, in cooperation with State and local governments, to use all practicable means to create and maintain conditions for a compatible existence between humans and nature. Each Federal department or agency involved in any action that affects the environment is required to observe all existing laws governing the control of pollution. All future construction is to be designed with pollution control in mind.

POLLUTION CONTROL REGULATIONS

In 1899 Congress passed a law prohibiting the discharge of refuse in navigable waters of the United States. The Oil Pollution Act of 1924 prohibited the discharge of oil of any kind (fuel oil, sludge, oily wastes, etc.) into the navigable waters. These Acts formed the basis for Article 1272, Navy Regulations 1948, which forbids the discharge of oil or refuse into inland or coastal waters. The Oil Pollution Act of 1961 prohibits the discharge of oil or oily mixtures, such as ballast, within specific zones bordering coastal nations. These prohibited zones extend a minimum of 50 miles seaward from the nearest land and out to 150 miles in some areas. Most countries bordering the Mediterranean Sea, for example, have a zone of 100 miles; the Australian zone extends 150 miles around most of the continent. Although this Act does not specifically apply to naval vessels, its provisions were incorporated into Article 1272 the following year. (The Act of 1961 is a ratification of an international agreement known as the Convention for the Prevention of Pollution of the Sea by Oil, 1954. Proposed amendments would abolish prohibited zones and extend oil dumping prohibitions to all ocean areas).

The Oil Pollution Act of 1924 was repealed by the Water Quality Improvement Act of 1970 (Public Law 91-224). (The Acts of 1899 and 1961 remain in effect, as does Article 1272 of Navy Regulations.) This Act prohibits the noncasualty discharge of any type of oil from any vessel, onshore facility, or offshore facility, into or upon navigable waters of the United States, adjoining shorelines, or waters of the contiguous zone (12 miles). Other features of the Act provide for the control of hazardous substances other than oil and for the control of sewage discharges from vessels.

The Clean Air Amendments of 1970 (Public Law 91-604) set goals for the reduction of pollutant emissions from stationary sources and from motor vehicles. New stationary sources that burn fossil fuels must conform to emission standards as determined and promulgated by the Environmental Protection Agency (EPA).

Guidelines for preventing, controlling, and abating air and water pollution are contained in the Navy's environmental quality program, OPNAV Instruction 6240.3. In general, the Navy is charged with ensuring that all facilities (ships, aircraft, shore activities, vehicles, etc.) are designed, operated, and maintained in conformance with standards set forth in the two Acts. Some of the most pertinent requirements of this instruction follow.

Municipal regional waste collection and disposal systems are to be used by shore activities whenever possible. All materials (solid fuels, petroleum products, chemicals, etc.) are to be handled so as to prevent or minimize pollution of the air and water. Resources are to be conserved by reprocessing, reclamation, and reuse of waste materials whenever feasible. Ships must use port disposal facilities for all wastes prior to getting underway and upon return to port. Oil products will not be discharged within any prohibited zone, and trash and garbage will not be discarded within 12 miles of shore; waste materials normally will not be burned in open fires. Sinking agents and dispersants will not be used for combating oil spills except when necessary to reduce hazard to human life, or when there is a substantial fire hazard.

In striving to meet requirements of the Clean Air and Water Quality Improvement Acts, the Navy has instituted several ongoing programs, some of which are in operation; others are being tested and evaluated. For example, completely enclosed firefighting training facilities from which no smoke escapes are now in operation. Aboard ship, the shift from Navy standard fuel oil to distillate will greatly reduce air pollution because of the distillate's low sulfur content. (It also is a cleaner-burning fuel.) Undergoing evaluation are several models of self-contained shipboard sanitary treatment systems that eliminate the discharge of polluted sewage.

OIL POLLUTION

The Navy, as required by a National Contingency Plan, has established a rapid response capability at each of its major naval bases to clean up oil spills emanating from naval vessels or shore facilities. At many naval activities, these capabilities include contractors, other Federal agencies, and municipal, civic, and other local and volunteer organizations. To provide adequate equipment for this purpose, the Navy, under the direction of the Naval Facilities Engineering Command, is pursuing a multi-year technical development and procurement program at the Naval Construction Battalion Center, Pt. Hueneme, CA. This program has already resulted in significant improvements in equipment and cleanup techniques. As new methods of improvements are developed, this information is used in equipment procurement and operator training programs.

RESPONSIBILITIES

The Chief of Naval Operations (CNO) issued OPNAVINST 6240.3E, which assigned specific responsibilities to the fleet commanders, area coordinators, the Chief of Naval Material, and other major claimants with respect to oil spill cleanup.

Area Coordinator

Area Coordinators assume the role of, or designate, on-scene coordinators and on-scene commanders for navy oil spills. They are responsible for planning contingency operations and for coordinating, with local commands and appropriate local, state, and federal agencies, the implementation of these contingency plans. They are also responsible for coordinating and implementing the development of effective and comprehensive contingency plans for naval activities within their areas.

On-Scene Coordinator

The on-scene coordinator (OSC), person predesignated by the Area Coordinator, is responsible for making all reports required by OPNAVINST 6240.3E and by any local instruction pertaining to reporting oil spills. Final message reports must be submitted within 24 hours after securing a cleanup operation.

When a report of a navy polluting incident is received, OSC must obtain full information concerning,

(1) Ship or activity involved;

(2) The location of the spill;

(3) The time and date of the spill, if known;

(4) The amount (in gallons) and type of oil spills, or the amount (pounds/kilograms) and type of hazardous substance(s) spilled;

(5) The primary and secondary causes of the spill, if known;

(6) The corrective action taken to stop, contain, and prevent recurrence by the reporting ship or activity, if any;

(7) The assessment of the help required (containment equipment and/or clean up equipment).

The OSC must also (1) designate an on-scene commander (OSCDR), (2) notify the personnel concerned with cleaning up the pollutant, and (3) take charge at the scene until the arrival of the OSCDR.

On-Scene Commander

The OSCDR reports directly to the OSC and assumes the responsibility for directing the manpower and equipment at the scene of the pollution, and utilizes all available resources to quickly remove the pollutant and to restore the environmental quality. Upon notification of a navy spill in local waters, the OSCDR takes immediate action to contain or isolate the spill by utilizing duty section personnel or personnel assigned to a spill recovery team and their equipment.

The OSCDR's responsibility is to determine the source of the spill, contain it, commence cleanup operations, and eliminate it.

If the navy spill occurs after working hours the OSCDR executes the recall bill, if necessary.

SPILL PHASES

When oil is spilled, it triggers a series of actions that are common to all spills and which have been categorized into the following operational phases.

1. Discovery and notification.
2. Evaluation and initiation of action.
3. Containment and countermeasures.
4. Recovery, mitigation, and disposal.
5. Cleaning and repositioning equipment.
6. Documentation and cost recovery.

Spill phases do not necessarily follow in sequence, but may and generally do, overlap. Figure 8-1 shows this overlap and summarizes some of the actions in each phase of an oil spill. Spill control operations can last anywhere from a few hours to several weeks and individual spills do not require the same degree of implementation for all the operational phases.

Phase I—Discovery and Notification

Discovery of an oil spill usually results from one or more of the following: (1) casual observation by personnel or the public, (2) result of monitoring and surveillance program, or (3) report made by the spiller. Whatever the mode of discovery, all Navy related spills must be reported.

Phase II—Evaluation And Initiation of Action

Upon notification and inspection of the spill, the Navy OSCDR must evaluate the following: (1) magnitude and severity of the spill, (2) potential impacts of the spill including hazard to life or property, (3) available response time, and (4) capability of local resources to handle the spill. Based upon this evaluation, the OSCDR should initiate local containment action and notify the Navy OSC. The OSC may either alert Regional Response Teams (RRT) or request assistance for spills which are beyond the local Navy response unit capability. The OSC will also evaluate the effectiveness of measures applied to the spill and maintain a detailed log of spill related activities. Spill samples should be taken as soon as possible after the spill and analyzed in accord with acceptable procedure. Data should be recorded for possible future use.

Phase III—Containment And Countermeasures

Containment and countermeasures are positive actions taken to limit the continued spread and migration of the spill and to stop the flow at the source. These steps are the first corrective actions to be taken, and should be initiated as soon as possible after a spill is discovered.

COUNTERMEASURES.—Typical countermeasures include:

1. The isolation and evacuation of the spill area to protect life or health.
2. The "Shut off" activities at the source of the spill. These may range from simple valve realinement to extensive salvage operations. Ruptured tanks, for example, may be sealed with chemicals which foam in place and form reliable seals.

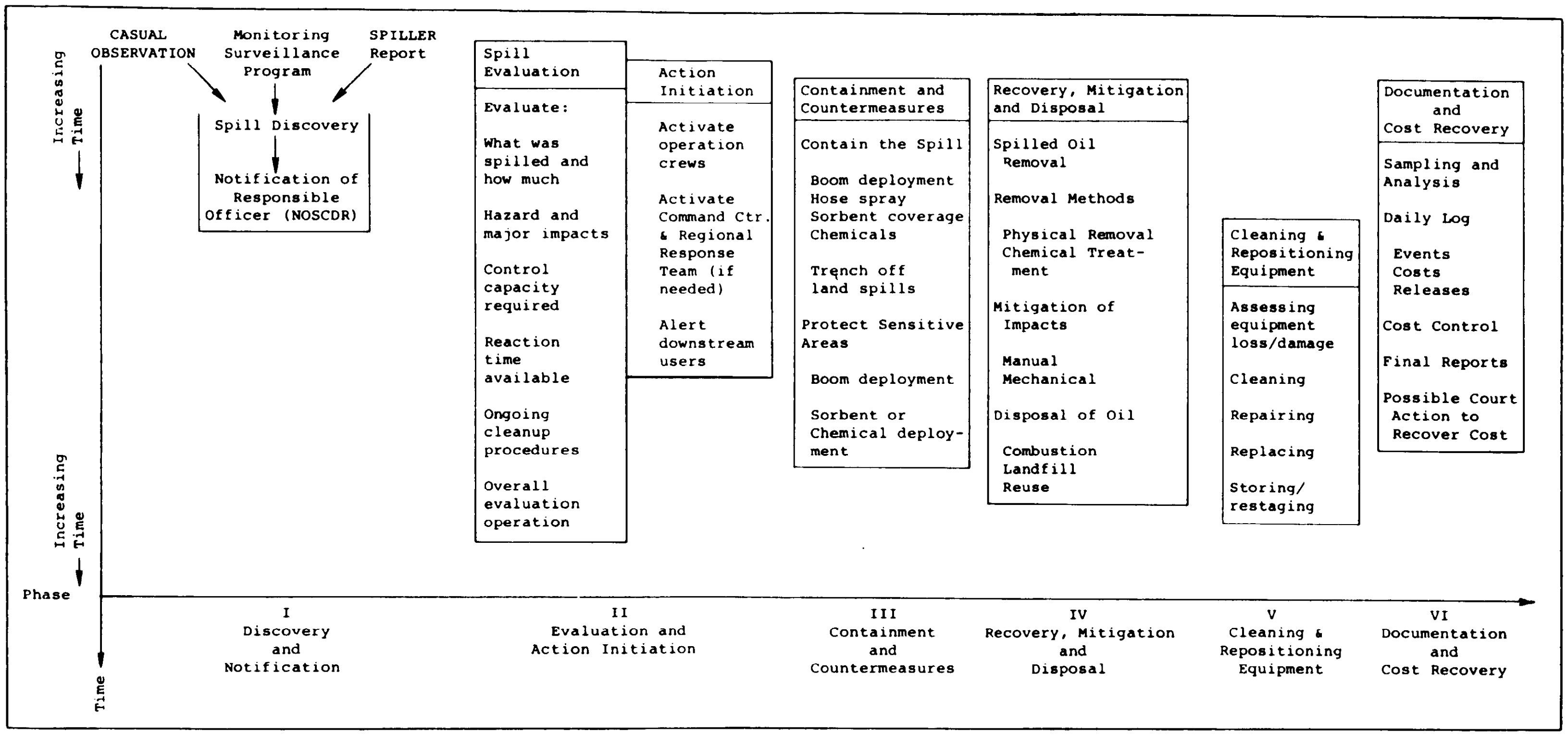

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Figure 8-1.-Operational Phases in an Oil Spill.

3. The placing of booms or other physical or absorbent barriers to prevent contact of the spill with areas of sensitive beneficial uses such as parks; estuaries, tributary streams, or water supply intakes.

4. The preplanned construction of trenches or dikes to isolate potential spill areas on land.

CONTAINMENT.—Containment is the critical first step of any coordinated spill cleanup activity. The rapidity and effectiveness with which it is applied will limit the adverse impacts of the spill on other beneficial uses of the affected water or land area. Table 8-1 summarizes some of the containment methods available.

Table 8-1.—Containment Methods

Type of System	Principle of Operation	Advantages	Disadvantages
Air Barriers	Subsurface bubbling to create upswelling of water surface	Do not impede vessel movement	Are costly to install and maintain. Are limited by environmental factors (wind, current).
Piston Film or Herder Chemicals	Surface tension phenomenon	Can be easily applied. Small dose required.	Only provides limited containment for a matter of hours. Government approved products must be used.
Booms	A physical barrier	Can be deployed quickly. Are physical barriers.	Work best in calm waters. May be used in limited currents and waves.
Hose Spray	Turbulent barrier to oil	Can be rapidly applied	Is limited to use in confined areas and calm water. Is temporary method.
Sorbent Barrier	Both physical barrier and absorbent surface for oil pickup	Can be easily deployed. Can be used for both containment and pickup.	Works best in calm water. Oil is not effectively contained. Slows spreading.

The Navy preferred containment equipment/procedures are piston film chemicals and solid, floating booms.

Piston Film Chemicals.—Piston film chemicals have high surface activity and spread rapidly over the water surface. The spreading force of the chemical is sufficient to overcome the spreading forces of the slick. These chemicals push the oil layer back until it reaches a limiting slick thickness, which the piston film cannot exceed. The oil may be moved ahead of the spreading film toward a collecting or containment device as shown in figure 8-2A, or the piston film may be quickly spread around the periphery of the spill as is shown in figure 8-2B. This technique simply slows down the spreading rate.

Containment Booms.—Containment booms are solid (floating barrier) booms. They are solid, continuous obstructions to the spread or migration of oil spills. Because they are the most effective containment device, they are preferred for use with Navy related spills.

1. Booms are available in various sizes (in 50-foot lengths) which are joined to form a continuous barrier to the oil. Their freeboard must be sufficiently high to prevent the oil from being washed over the boom, and the skirt long enough to prevent oil from being swept under it. Booms are purchased in several height/depth sizes to meet their use requirements under various wind and sea conditions.

2. Booms may be used in either a dynamic (towed) mode or in fixed position. Figure 8-3.I shows a boom being towed in a "vee" configuration in conjunction with a skimming device. The boom directs the oil to the skimming device where it is collected.

3. Booms are also being used to prevent oil from going under the pier and to direct the oil to the skimmer (figure 8-3.II). The slick is moved to the skimmer under the influence of wind and current, or it could be pushed toward the skimmer by hose spray, air jet, or piston film, if necessary.

4. Booms may be anchored in a position that will entrap the oil but leave a channel open for navigation if necessary (figure 8-3.III). The angle at which the boom must be set is important in order to avoid loss of collected oil due to entrapment in the current or from being carried under boom skirts.

5. Figure 8-3 .IV depicts typical use of a boom stretched across a stream. This alinement is feasible in small streams, mild currents, or tidal

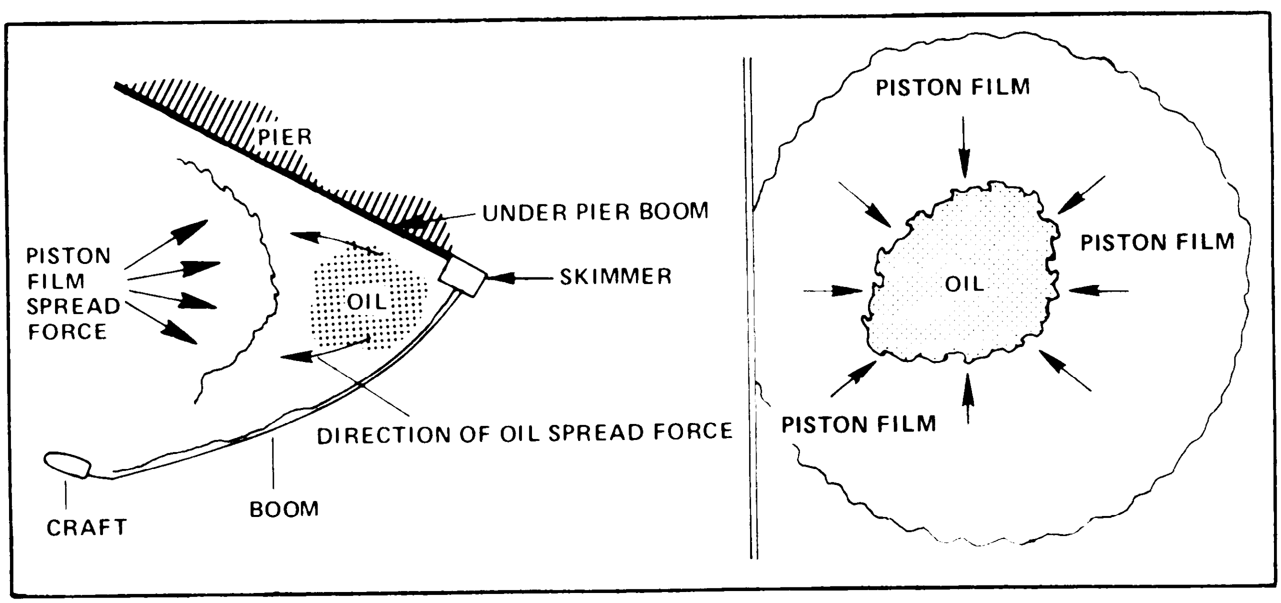

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Figure 8-2.—Use of Piston Film Chemicals.

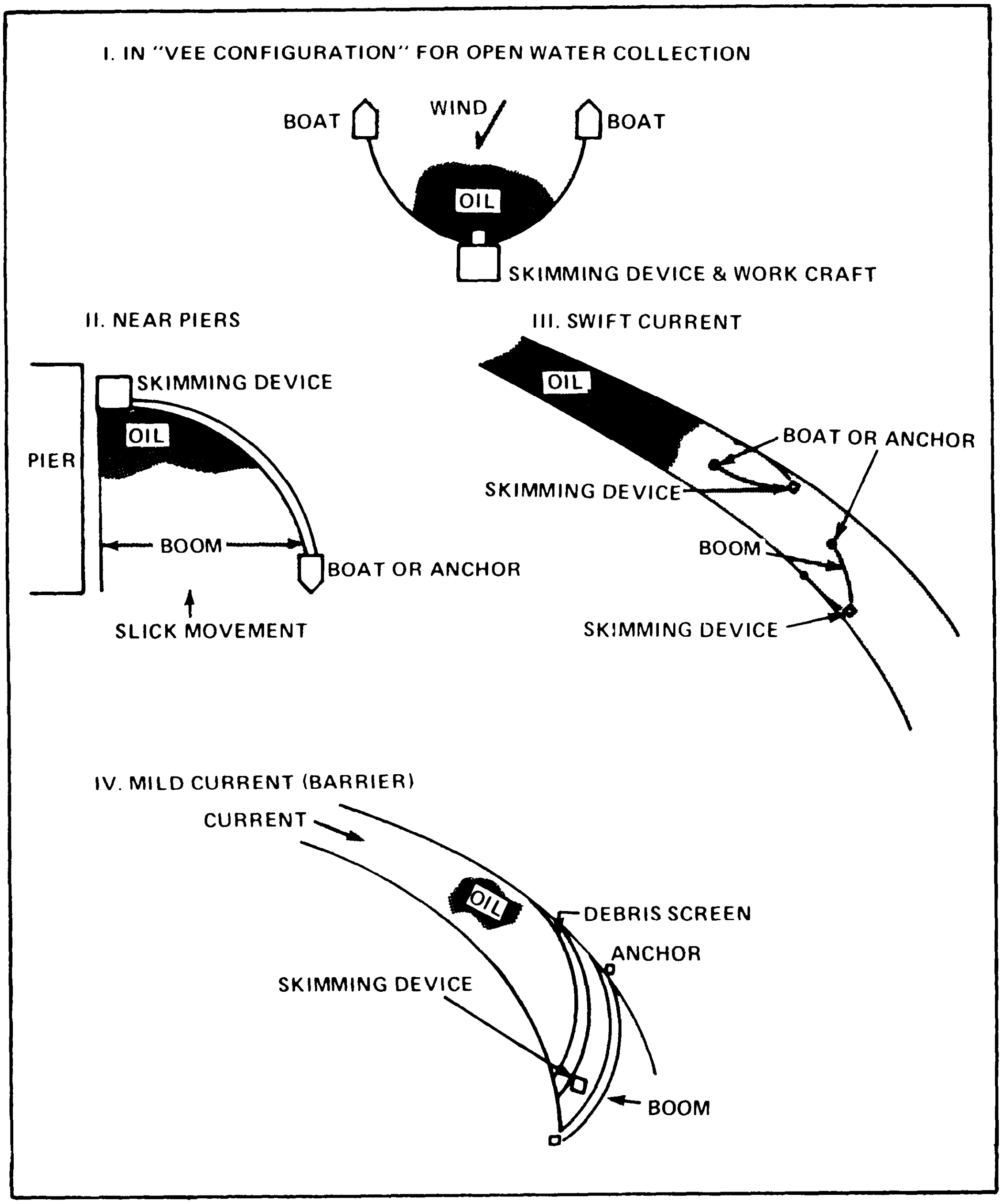

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Figure 8-3.—Typical uses of floating booms.

fluctuations. As depicted, diagonal deployment, in lieu of perpendicular, has been generally found more effective in flowing streams.

Procedures to contain spills on land vary with the amount and type of oil spilled, the type of soil and the terrain. Less viscous oil and more porous soil allow greater and more rapid penetration and lateral migration in the soil. Where feasible, absorbent materials should be applied as soon as possible. Larger spills may require containment devices such as interceptor trenches or collecting pools from which the oil may be pumped.

Spill containment by the use of hose spray can be an effective method in confined areas. This technique is immediately available to ships' forces and provides the earliest form of containment.

Phase IV—Recovery, Mitigation, and Disposal

This phase of an oil spill involves those actions taken to recover spilled oil from the affected environment as well as the monitoring activity associated with determination of the effectiveness of the cleanup operation. It includes those actions taken to mitigate damage cause by the spilled oil, and to dispose of the recovered oil in an environmentally acceptable manner.

REMOVAL.—Removal of spilled oil and oil derivatives may be accomplished several ways, including:

1. Allowing evaporation to take place (gasoline and JP-4).
2. Use of physical removal methods such as manual collection or collection by mechanical equipment, such as skimmers.
3. Removal by fostering biodegradation.
4. Removal by burning.
5. Removal by dispersion (emulsification).
6. Pumping of oil in land spills.

Because of effects which are detrimental to the environment, method 4 is not recommended, or practiced, by the Navy unless there is a direct threat to human life and property. Because of the lengthy reaction time involved, and because of the possibility of toxic by products, method 3 is not practiced nor recommended as a desirable Navy practice. However, it may occur, and can constitute a final polishing action if all the oil is not removed by physical means.

In addition, gelling agents (chemicals which convert the spill to a semisolid mass) or sorbent materials such as straw, polyester plastic shavings, or polyurethane foam may be used to help the subsequent manual or mechanical removal of a spill.

PHYSICAL REMOVAL METHODS.—The Navy prefers physical-mechanical methods of removal, and has designated the types of skimmers for use with Navy spills in various locations.

1. Small Skimmers. The <u>small unit</u> which is designed for use in congested harbor areas is based on the weir principle. The weir depth of these skimmers is controlled by adjusting the flow rate of the attached pump. As the flow rate is increased, the fluid is removed from the rear buoyancy chamber, tipping the unit clockwise, and thereby increasing the weir depth. Decreasing the flow rate allows the buoyancy chamber to fill, tipping the unit counterclockwise, and thereby reducing the weir depth. This unit is most effective in a stationary mode where it is positioned and the oil directed to it.

2. Medium Skimmers. The <u>medium skimm</u>er selected by the Navy is an "endless" belt unit. It is operable from a pier via handheld controls. The principle of operation is shown in figure 8-4. The rotating belt submerges the oil and directs it to the collection well where it concentrates and from which it eventually is pumped to a temporary storage. This principle is entitled the dynamic inclined plane (DIP^{tm}).

3. Large Skimmers. The <u>large ski</u>mmer selected for use by the Navy is a larger version of the medium skimmer (DIP^{tm}). This unit is vessel-mounted for use in protected open waters, and is quite effective even in choppy water in that it overruns and submerges the oil layer before collecting it. A rotating belt directs the oil to the collection well.

4. Suction Based Skimmers. Other commercially available units for oil removal are based on suction, either taken directly off the surface of the water or by the development of a submerged vortex. Since these units are highly susceptible to wave action and clogging, they work best in calm,

debris-free waters, and with thick oil layers. They are not extensively used for Navy spills.

5. Sorbent Surface Skimmers. These units use an endless belt, hose, or rotating drum, the surface of which absorbs the spilled oil from the water surfaces. The concept is applied in large, craft-mounted units for large spills and in smaller units using an endless, hose-width belt. The absorbed oil is conveyed to temporary storage tanks where it is squeezed from the belt or wiped from the drum or disc.

6. Manual Methods. Occasionally, manual removal methods are used in the Navy. Manual removal processes involve the physical pickup of the oil from shoreline areas with the use of sorbent materials, pitchforks, and/or shovels. They also include "in water" removal operations such as that mounted for small shipside spills in which the Mark I Spill Control Kit is employed. In this instance, herder chemicals may be used to retard spreading of the spill, and hand-held polyurethane absorbent pads or "mops" are used to "sorb" and remove the oil. The pads are squeezed out with conventional mop wringers.

Chemical Removal Methods.—Chemicals should not be used to emulsify, disperse, solubilize, or precipitate oil whenever the protection or preservation of freshwater supply sources, major shellfish or finfish nurseries, harvesting, grounds, passage areas, or beaches is a prime concern.

Such chemicals should only be used in those surface water areas and under those circumstances where preservation and protection of water related natural resources is judged not to be the highest priority or where a choice as to resource preservation may make the use of such materials a necessary alternative. When chemical compounds are used in connection with oil cleanup, only those compounds exhibiting minimum toxicity toward aquatic flora and fauna should be used. The EPA is now developing, and will soon issue, a standard procedure for determining the toxicity of such chemicals.

Now let's describe some of the chemical removal methods used.

1. Dispersants. Dispersants (emulsifiers) are surface active agents which foster the development of oil/water emulsion. They may be ionic or nonionic in nature and are typically mixed with stabilizers, to preserve the emulsion formed, and solvents for cold weather use when surfactant viscosity is reduced. A typical dispersant is about 70-80% solvent, 10-15% surfactant and 10-15% stabilizer.

The use of dispersants exposes a great surface area for microbiological attack. However, many

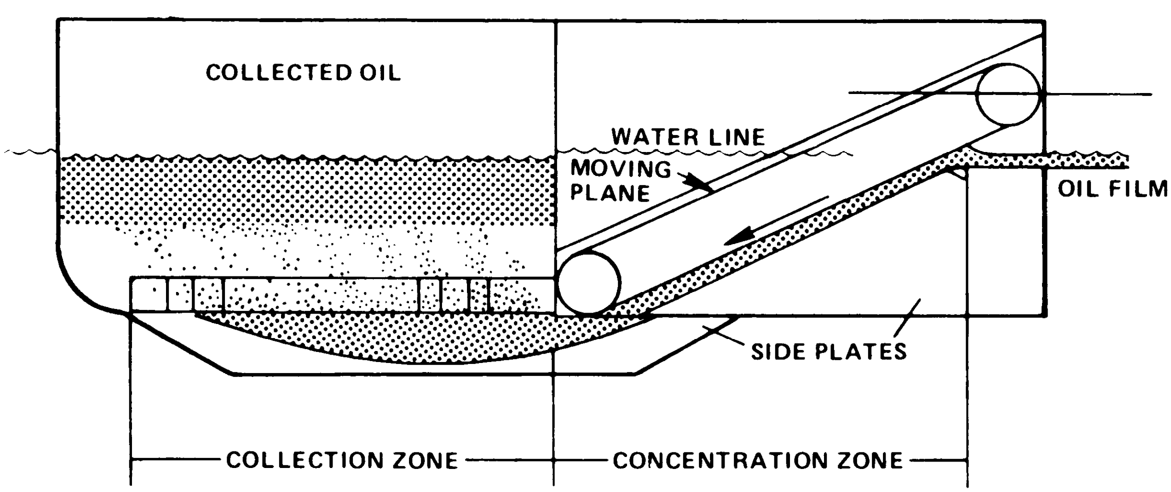

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Figure 8-4.—Principle of Operation of Dynamic Inclined Plane (DIP) Skimmer.

of the surfactants are not degradable; and they, or the materials with which they are mixed, may be toxic to microorganisms and aquatic species. By dispersing, they distribute the oil throughout the water column, extend its area of influence considerably, and have a resultant adverse biological impact. Also, dispersant may have a short effectiveness period; and the oil is released and resurfaces. In fact, dispersion is not really a removal method but rather one of spreading the oil and reducing its visibility.

2. Sinking Agents. Sinking agents are materials such as clay, fly ash, sand, or crushed stone which when applied to spilled oil will sink it. Sunken oil will cover and smother or taint the bottom (benthic) organisms, including shellfish. Additionally, it will move and resurface as a result of turbulence or microbial degradation. For this reason the use of sinking agents is prohibited by Federal regulations.

3. Gelling Agents. These materials absorb, congeal, entrap, and fix the oil to form a semi-rigid or gelatinous mass, which may be more easily recovered, or will inhibit the spread of the spill. Gel agents include soap solution, wax, fatty acids, and various polymers.

4. Burning Agents. The loss of volatile components and the incorporation of water make oil spills difficult to ignite and sustain in the burning condition. The use of burning agents is essential if burning is to be pursued, and approved, as a disposal means. These agents contain combustion promoting and sustaining chemicals. Their use may be authorized by the OSC when it will prevent or substantially reduce hazard to life or property. Such instances are rare in inland waters, and burning should be avoided.

DISPOSAL.—As oil is recovered from the spill area, it must be pumped to a storage area or container where oil/water separation is initiated or continued. Gravity separation, centrifugation, and other separation techniques are available in commercial equipment. The concentrated oil is then removed to transport facilities and conveyed to recycle or disposal sites.

Once oil has been removed from the spill site, the major battle may have been won; but the conflict goes on, because unless the oily waste or oiled debris is properly disposed of by the Navy activity or contract operator, it can and will become a problem at the disposal site. The conventional disposal methods listed in Table 8-2, for example, may allow the oil to recontaminate surface or ground waters, degrade the air quality, or present fire hazards. Damages resulting from any unauthorized disposal of oil by the Navy or its contractor may lead to litigation.

The disposal options are essentially limited to (1) reuse; (2) disposal by soil cultivation techniques; (3) controlled burning; or (4) placement in “approved” sanitary landfills.

Reuse of the oil collected from the spill is to be preferred where it is possible. The recovered oil may be “re-refined” and recycled for beneficial use. Re-refining facilities are not always readily accessible from spill sites, but the possibility of reuse should always be considered.

MITIGATION.—Oil spills will affect the beneficial uses of the water or land with which they have contact. Mitigation deals with the removal of oil from the area to the degree necessary to permit resumption of the original use of the water or area.

Mitigation operations are response actions which may not involve much removal of the pollutant, but are desirable to lessen the impact of the spill.

Restoration activities may include shoveling up asphaltic or tarry residues of the spill; application of hot water washes on rocky shorelines; extensive manual or mechanized efforts to collect, reclaim, and reestablish affected beach sand; or trenching of estuaries to remove as much oil as possible. Most restoration efforts deal with beach areas, where the procedures selected vary with the type, age, and amount of spilled oil and the type of beach affected. Generally, lighter oils (less viscous) penetrate the sand more rapidly, and require the use of techniques that include harrowing in sorbent material to foster degradation, sand pickup, reclamation and/or replacement. Treatment of beach sand to remove oil can only be justified where beach sand is scarce and its

Table 8-2.—Summary of Spilled Oil Disposal Techniques

Disposal Technique	Equipment Required	Advantages	Disadvantages	Comments
Controlled Burning	Incinerator and appropriate feed/storage device.	Good volume reduction with a small amount of inert ash for disposal.	Could be the cause of smoke, odor and particulate emissions.	May need air pollution control system. May be used beneficially in fire-fighting training.
Open Burning	A method of land application (pumps, nozzles, hoses, etc.).	Very economical and simple in its concept and operation.	Will create air pollution, especially smoke. May be a safety problem.	Should not be considered except under favorable meteorological conditions and when there is no other choice.
Sanitary Land Fill	Approved land area. Earth moving equipment.	Satisfactory disposal method.	May create safety hazard. May cause a leachate problem.	May not be acceptable, in many areas, to regulatory officials.
Burial	Acceptable land area. Earth moving equipment.	Simple technique. Economical disposal method.	May create a leachate problem.	Subject to regulatory control.
Land Spreading	Method of land application (pumps, nozzles, hoses, etc.).	Very inexpensive. Very simple.	Safety and fire hazard.	Subject to regulatory approval.

replacement is costly, because the current methods for beach sand reclamation are very expensive.

Mitigation of impacts may also involve biological reseeding of areas affected by the spill or the cleanup operations. It may also include the collection, cleanup, and care of oil soaked birds, which were attracted to the spill area, although this effort is generally only partially effective. It requires expert knowledge, facilities for recuperation, and extensive use of manpower.

As you read earlier in this chapter there are six operational phases involved with spills. We have briefly discussed only four of these. For more detailed information about the phases discussed and additional information on the care of the equipment and administrative follow up to a spill read and study NAVFAC P-908, Oil Spill Control for Inland Waters and Harbors.

CAUSES OF OIL SPILLS

The frequency of occurrence and the volume of oil spilled in relation to the various causes as reported to, and compiled by, the Navy Environmental Support Office (NESO) is shown in table 8-3. You can clearly "see" that human error is involved in the majority of these spills.

The best way to help cope with this problem of "human error" is through the proper training of operational personnel. This should include study of pertinent regulations and operational procedures; adherence to the Personnel Qualification System (PQS) and periodic drills involving cleanup procedures and operation of oil spil1 cleanup equipment.

In addition to routine and schedule maintenance, as well run facility should perform and log periodic inspections dealing with the

Table 8-3.—Navy Related Oil Spills by Cause (1975)

Cause	No. of Spills	Percent Total Spills	Volume Spilled (gal)	Percent Total Vol. Spilled	Av. Vol. of Each Occurrence
Valve misaligned (open)	39	9.4	3,943	3.4	101
Monitoring error	80	19.2	6,792	5.8	85
Donut (WOR)	16	3.8	794	.7	50
Collision	1	.2	1,500	1.3	1,500
Grounding	0	-	-	-	-
Structural/design failure	95	22.8	52,267	44.5	550
Tank overflow	27	6.5	3,305	2.8	122
Fuel transfer					
(internal)	3	0.7	178	0.1	58
(external)	14	3.4	1,824	1.6	130
Air in line	7	1.7	74	.l	11
Unknown	124	29.7	39,744	33.8	321
Other	11	2.6	7,143	8.1	649

prevention of accidental oil spills. Tanks, pipelines, and valves should be periodically inspected for corrosion. The proper operation and sealing of valves and pumping units are a must.

A daily record of tank levels, and observance of standard operating procedures for many shore facilities and all ships, are effective ways for detecting slow leaks before a major equipment failure occurs. Hydrostatic testing of hoses, pipelines and storage tanks should be performed periodically to verify their use for oil service. Operating personnel should be encouraged to report unsafe conditions in equipment or procedures. Another good practice is to report and document causes of oil spill "near misses" so that preventive action can be initiated. All inspections and records should be in accordance with established written procedures and should remain on file for the use of new personnel and for the identification of deteriorating trends in equipment.

The Navy is expending time, money, and effort to reduce environmental pollution. Therefore, close supervision must be exercised over all operations involving fuel handling, waste disposal, and use and disposal of toxic materials. Personnel must be aware of pollution problems and the necessity to reduce pollution occurrences. Within one's area of responsibility, regular inspection and monitoring procedures must be conducted to ensure compliance with all applicable regulations and operating procedures for pollution control devices.

You will find more detailed information on oil spills in NAVFAC P-908. This publication will provide you with information about policy, rules, regulations, and procedures for the prevention of oil spills. It will also provide you with information on what type of equipment is used to remove/contain oil spills, what are the procedures for cleaning the equipment, and what procedures to follow when reporting the cost of an oil spill.

COLLECTION, HOLDING, AND TRANSFER SYSTEM

The environmental effects that result from sewage discharges into rivers, harbors, and coastal waters by naval ships are of great concern to the Navy. The Navy is required to control sewage discharges under regulations promulgated by the Secretary of Defense. Navy policies and responsibilities are defined in OPNAVINST 6240.3.

The Navy plans to equip each naval ship with a marine sanitation device (MSD) which will enable a ship to comply with the sewage discharge standards without compromising the ship mission capability.

Sewage discharge regulations do not preclude overboard discharge when an emergency situation exists and when failure to discharge would endanger the health and safety of personnel.

In the past, shipboard sewage has been discharged overboard as a matter of routine. Studies have shown that concentration of sewage in inland waters, ports, harbors, and coastal waters of the United States had detrimental effects on the environment.

In 1972, anticipating the present regulations, the CNO made the policy decision to install the Sewage Collection, Holding, and Transfer (CHT) system aboard naval ships which could employ this method of sewage pollution control without serious reduction in military capabilities. The CHT system represented the least cost and risk solution to the problem.

The design goal of the CHT system is to provide the capacity to hold shipboard sewage generated over a 12-hour period. This goal can usually be achieved in large ships. Smaller ships, where the maximum capacity limits holding times to 3 hours or less, which is insufficient time to transit a 3-mile restricted zone, cannot achieve such a goal.

ELEMENTS OF THE CHT SYSTEM

Most operational fleet ships of sufficient size will be equipped with CHT systems. This system is designed to accept soil drains from water closets and urinals and waste drains from showers, laundries, and galleys. As the name of the system implies, sewage collection, holding, and transfer are three functional elements which constitute the CHT system.

Collection Element

The collection element consists of soil and waste drains with diverter valves. Depending on the position of the diverter valves, the soil or waste can be diverted overboard or into the CHT tank. The basic CHT system concept requires that waste drains be kept separate from soil drains wherever practical until they reach their respective overboard diverter valves. Downstream of their overboard diverter valves both waste drains and soil drains may be combined into a single drain line. All drains above the waterline may be diverted overboard by gravity. Drains located below the waterline cannot be diverted directly overboard and must use the CHT system as an ejection system. In this case, the CHT system must operate continuously in all modes.

All drain piping is pitched to insure rapid and complete drainage. Pitch is 1/4-inch/ft whenever possible, but not less than 1/8-inch/ft relative to the operating trim.

Garbage grinder drains connected to the waste drains are installed with a minimum slope of 3 inches/ft. Garbage grinder drains are also provided with a check valve to preclude back-flow from the waste drain and a diverter valve to permit drainage to either the CHT tank or overboard. When the garbage grinder employs seawater for flushing, the waste piping downstream of the garbage grinder is of copper-nickel alloy.

Plumbing drains may penetrate watertight bulkheads. Usually, each bulkhead penetration below flooding water level (FWL-1) is provided with a bulkhead stop valve. The stop valve is a round, full-port plug or ball valve. The stop valve is operable at the valve and the damage control deck. In some installations, diverter valves (3-way valves) are used to prevent progressive flooding throughout the CHT system drains, eliminating the need for a bulkhead stop valve.

Where CHT system valves are designated as damaged control closures, the valve bonnet and hand wheel is labeled SET X-RAY, SET YOKE, or SET ZEBRA, with the direction to be turned marked with an arrow. Similar labeling is required at the damage control deck box. The damage control labeling is in addition to the CHT classification and label plate.

Holding Element

The CHT tank is usually sized for a 12-hour holding period. Individual ship constraints may affect this design objective. Each tank has inside surfaces which are usually free of structural members such as stiffeners, headers, and brackets. Very large tanks may require swash bulkheads to dampen movement of the tank contents. The tank bottom slopes approximately 1.5 inches/ft toward the pump section. All internal surfaces of the tank are coated in accordance with procedures given in the Naval Ship's Technical Manual chapter 63(9190). Preservation of Ships in Service, for protecting sanitary tanks, and to prevent corrosion. Each CHT tank is fitted with a vent to the atmosphere and an overflow to the sea. In addition, a manhole is provided for internal maintenance. Vents should be positioned to avoid intake of CHT gases into the air compressor or ventilation intakes.

Transfer Element

Each tank is equipped with two nonclog marine sewage pumps connected in parallel. The pumps may discharge sewage to a tender, barge, shore facility, or directly overboard, depending on the position of the discharge diverter valve. Each pump is equipped with full-port plug or ball suction and discharge valves, and a discharge swing check valve with a hold-open device. An explanation of pump characteristics curves is given in Naval Ships' Technical Manual, Chapter 503(9470), Pumps.

System Types

Two types of CHT systems are installed. The type selected for a particular ship depends on the holding tank capacity. Systems with tanks with a capacity of more than 2000 gallons use a comminutor and aeration system. Smaller systems with tanks having a capacity of less than 2000 gallons use strainers.

Comminutor

In a comminutor-type system the comminutor located in the soil drain or the combined soil and waste drain serves to macerate solids passing into the CHT tank. A bypass is fitted upstream of the comminutor. If the comminutor jams or plugs, the bypass provides drainage around the comminutor and into the tank. If a valve is fitted in the bypass, it should always remain open. Isolation valves are fitted directly before and after the comminutor to allow for maintenance. Most installations include an access port, or cleanout, to permit removal of foreign objects which may jam or plug the comminutor. The components of the comminutor-type system, shown in figure 8-5, include:

1. The CHT tank. The capacity of each tank usually is more than 2000 gallons.

2. The CHT pump set; one pump set per tank. A pump set consists of two motor-driven pumps, two suction plug or ball valves, two discharge plug or ball valves, two discharge check valves (with hold-open device), a pump controller, a high level alarm, and an appropriate number of liquid level sensors.

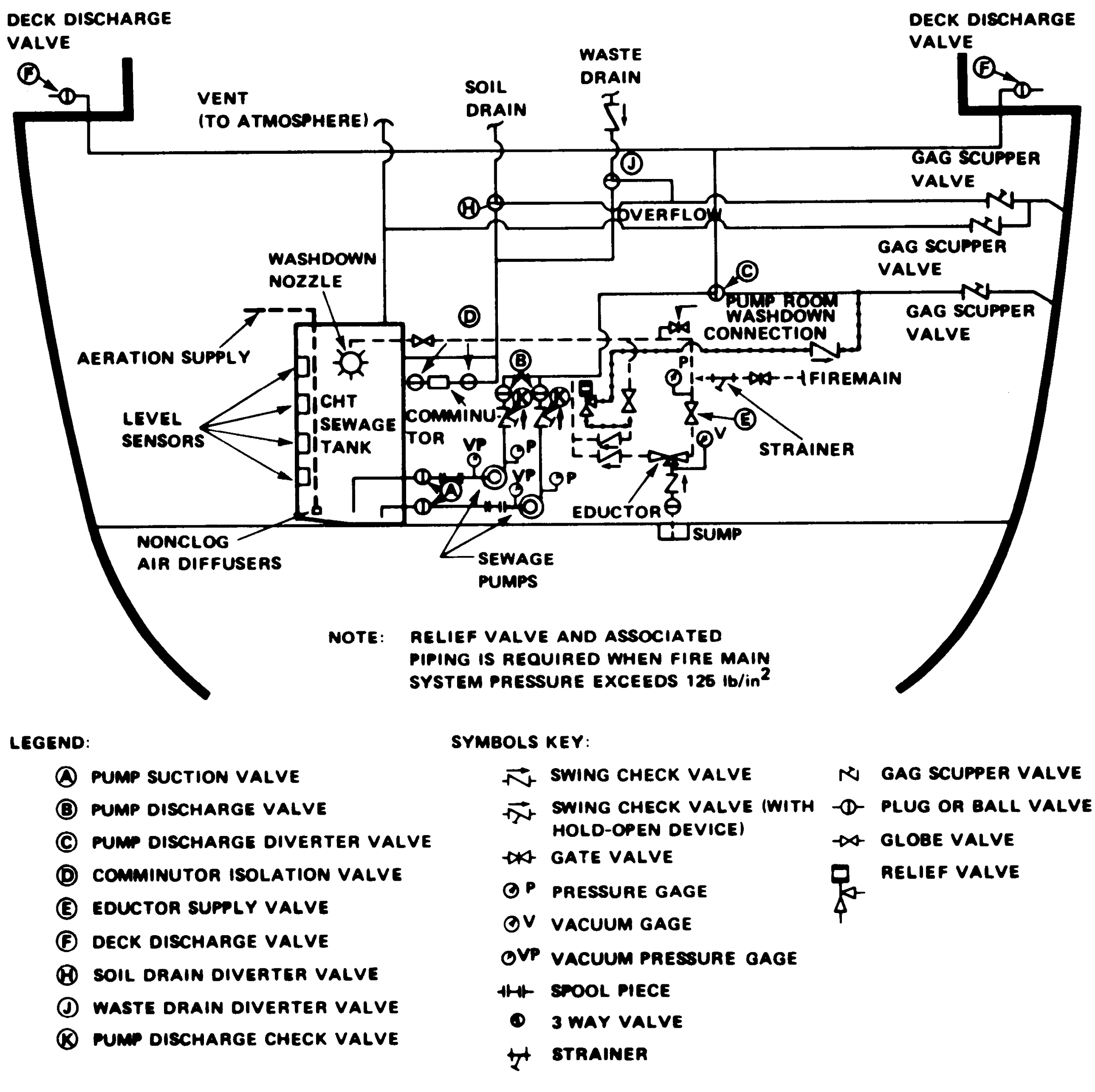

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Figure 8-5.—Comminutor type CHT system.

3. The comminutor. One comminutor is located in each soil drain or combined drain entering each tank.
4. The aeration supply system.
5. The firemain flushing connections and spray cleaning nozzle for tank washdown.
6. The piping, valves, and fittings.

Strainer

The strainer-type system incorporates an overflow strainer within the CHT tank and an inflow strainer mounted on the discharge side of each pump. The drain collection piping directs sewage flow through the overflow strainer where liquids may overflow into the CHT tank if the inflow strainer or the pumps become clogged. Solid and liquid wastes flow through the ball or plug valve and the check valves until they reach the pump discharge piping. At this junction, the sewage flow passes through the inflow strainer where large solids are collected, then through the pumps, and back into the CHT tank. The inflow strainer limits the flow of solids, but liquids are allowed to pass through the pump into the tank. Each time the pump operates, its inflow strainer is cleaned by the reverse flow of liquid being pumped from the tank. The strainer-type system components, shown in figure 8-6, include:

1. The CHT tank. The capacity of each tank usually is less than 2000 gallons.
2. The CHT pump set; one pump set per tank. A pump set consists of two motor-driven pumps, two suction plug or ball valves, two discharge plug or ball valves, two discharge check valves (with hold-open device), a pump controller, a high level alarm, and an appropriate number of liquid level sensors.
3. The Firemain flushing connections and spray cleaning nozzle for tank washdowns.
4. The piping, valves, and fittings.

CHT OPERATIONAL MODES

The CHT system can be used in any of three district modes of operation in accordance with any one of the following situations:

1. Transiting Restricted Zones. When transiting restricted zones, the CHT system must be set up to collect and hold the discharges from soil drains only.
2. In Port. During in-port periods, the CHT system collects, holds, and transfers to shore sewage facility all discharges from soil and waste drains.
3. At Sea. When operating at sea outside restricted areas, the CHT system is set up to divert discharges from both soil and waste drains overboard.

Transmit Mode

While transiting a restricted zone, soil drains are routed to the CHT tanks and the waste drains are diverted overboard. Both CHT pump controller switches are in the OFF position. Pump suction valves A and inflow stop valve G (for strainer system only). are open (see figure 8-6). Pump discharge valves B and the tank washdown supply valve are closed. Soil drain diverter valves H are in the CHT COLLECTION position. Waste drain diverter valves J are in the OVERBOARD position, discharging through the gag scupper valves.

For systems equipped with a comminutor (see figure 8-5) and an aeration system (see figure 8-7), open the comminutor isolation valves, D and operate the comminutor. The tank contents must be aerated continuously. Operate the air blower and open discharge valve M (shown in figure 8-7). Air also can be supplied by opening the ship service air supply valve N (also shown in figure 8-7). If an aspirator system is employed, the aspirator pump should be activated.

WARNING

Whenever a high level alarm sounds, immediate action must be taken to close the isolation valves on drains below the overboard discharge and to divert upper level drains overboard to preclude flooding of spaces.

After sewage transfer hose connections are completed, both soil and waste drains are routed to the CHT tank and then discharged to a shore receiving facility, nested ship, or barge receiving station. When connecting the sewage transfer hose, proper chafing gear and supporting lines

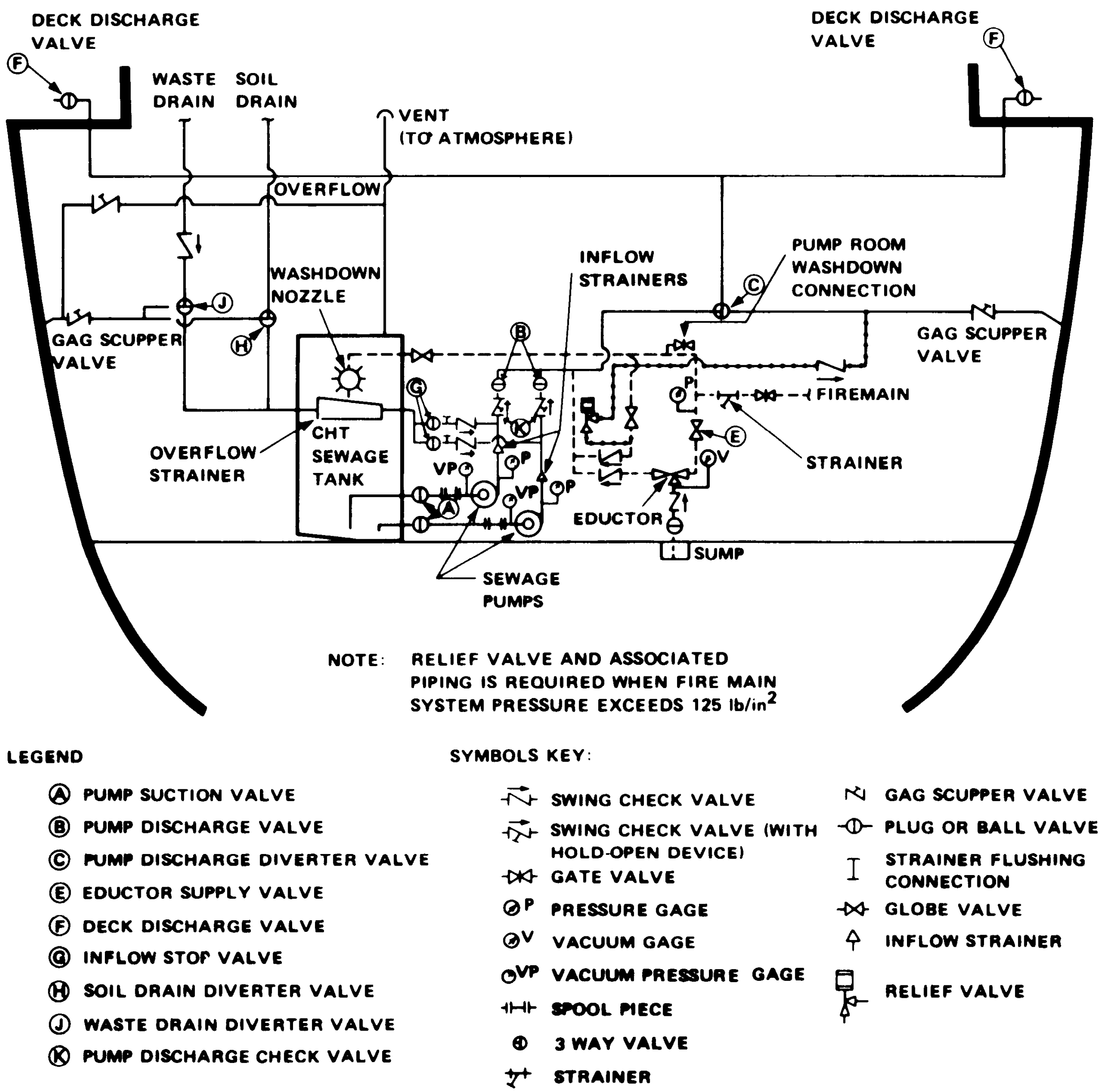

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Figure 8-6.—Strainer-type CHT system.

should be fitted where required to protect the hose. Care should be taken to prevent the hose from snagging between the ship and the pier.

Valves A, B, and C should be lined up and set for discharge to the shore side deck discharge at valve F. The receiving station sewer valve should then be opened, followed by valve F at the deck connection. With a person stationed at deck connection F, pass the word to the CHT pump room that hose connections have been made (see figures 8-5 and 8-6).

Set both pump controller selector switches to AUTO position. Set soil drain diverter valves H and waste drain diverter valves J to the CHT COLLECTION position for drainage to the CHT tank. After the tank is pumped down and the

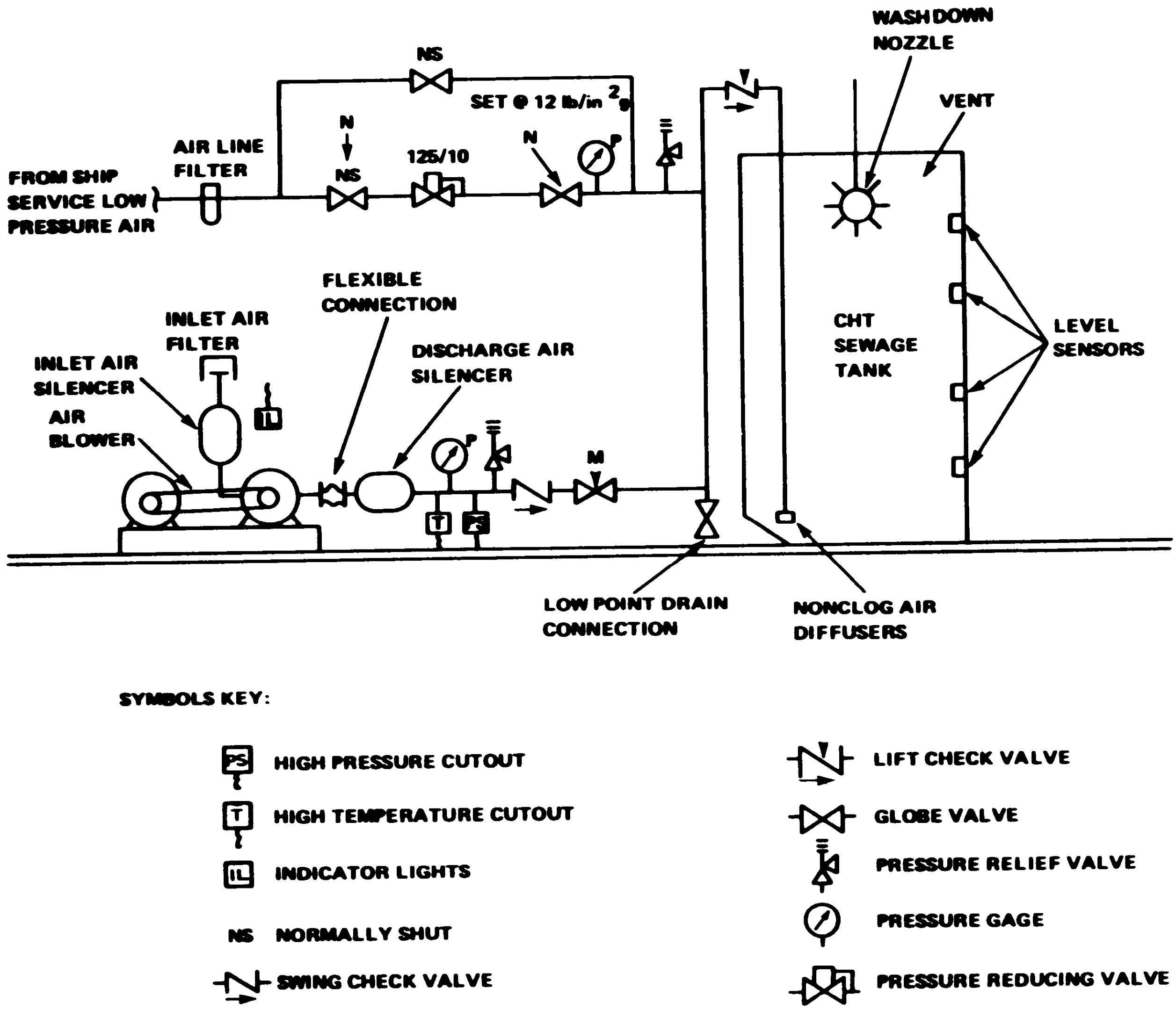

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Figure 8-7.—Aeration subsystem.

pump stops, open the tank washdown supply valve and wash the tank for 30 minutes. Close the tank washdown supply valve.

The comminutor and aeration system should be operated continuously in the in-port mode. During extended in-port transfer operations, the CHT tank must be washed a minimum of 30 min/wk. While discharging waste through transfer hoses, check periodically for leakage, kinking, and snagging.

In the event of a high level alarm, the operator should recognize that a problem exists with the pumps, the discharge piping, or both. If the tank completely fills while the system malfunction is being investigated, the waste will overflow overboard and through any heads or fixtures located below the overflow discharge lines. Drain lines from these fixtures incorporate both a check valve and an isolation, or cutoff, valve. These fixtures must be identified prior to initial system use. Whenever a high level alarm sounds, immediate action must be taken to close the isolation valves on drains located below the CHT tank overflow line discharge and divert upper deck drains overboard to preclude flooding of space. In the event of leakage or snagging of the transfer hoses, close valve F (shown in figures 8-5 and 8-6) at the deck connection only (closure of pier valve may cause the discharge hose to rupture). Line up pump discharge diverter valve C for overboard discharge, to prevent overflow or backup of drains located below the tank overflow.

At-Sea Mode

In order to set the CHT system up for the At-sea mode (refer to figures 8-5 and 8-6) set soil and waste drain diverter valves H and J to the OVERBOARD position. Open pump discharge valves B and set pump discharge diverter valve C to the overboard position. Check to insure that gag scupper valve at the hull in the pump discharge line is open. Set the discharge pump controller selector switches to the MAN1 position. After the pumps lose suction, set both controller selector switches to the AUTO position. Open the tank washdown supply valve and wash the tank for 30 minutes. Close the tank washdown supply valve. Set the controller selector switches to MAN1 position. After loss of pump suction, set controller switches in the OFF position. Close pump suction valves A, discharge valves B, and, in the strainer system only, close the inflow stopvalves G.

For CHT systems outfitted will comminutors and aeration systems, secure the comminutor after setting the soil drain diverter valves. Close air blower discharge valve M and secure air blower, or close ship supply valve N after tank washdown procedures have been completed and the pump has lost suction. If an air aspirator system is installed, shut the system down and secure the aspiration pump.

The CHT system is now secured with all soil and waste being discharged overboard through the gravity drainage system.

For additional information on the CHT system and its components, refer to the manufacturer's technical manuals and Naval Ships' Technical Manual, Chapter 593.

NOISE POLLUTION

Hearing loss problems have been and continue to be a source of concern within the Navy, both ashore and afloat. In the Navy the loss of hearing can occur from exposure to impulse or blast noise (i.e., gunfire, rockets, etc.) or from continuous or intermittent sounds such as jet or propeller aircraft, marine engines, boiler equipment operations, and any of a myriad of noise sources associated with industrial type activities (such as shipyards). Hearing loss may be temporary, and will disappear after a brief period of nonexposure, or it may become permanent through repeated exposures to intense noise levels. The loss of hearing sensitivity is generally in the higher frequencies of 4000-6000 Hertz (Hz) with many people sustaining extensive impairment before the all important speech range of 500-3000 Hz is appreciably affected.

The Navy recognized noise pollution to be a problem and started to combat it through the Hearing Conservation Program. The main purpose of this program is to establish and implement an effective occupational noise control and hearing conservation program which has as its goal the elimination/prevention of hearing loss.

HEARING CONSERVATION PROGRAM

Hearing loss associated with exposure to hazardous noise and the high cost of compensation claims have highlighted a significant problem which requires action to reduce or eliminate hazardous occupational noise levels. An effective occupational noise control and hearing conservation program will prevent or reduce the exposure of personnel to potentially hazardous noise. Such programs will incorporate the following elements:

1. Identification of hazardous noise areas and their sources.
2. Elimination or reduction of noise levels through the use of engineering controls.
3. Periodic hearing testing of noise-exposed personnel to evaluate program effectiveness.
4. Education of all hands in the command's program and their individual responsibilities.
5. Strict enforcement of all prescribed occupational noise control and hearing conservation measures including disciplinary action for violators and supervisors, as necessary.

RESPONSIBILITIES

The Secretary of the Navy policy, contained in SECNAVINST 5100.1D, emphasizes that occupational safety and health are the responsibilities of all commands. Accordingly, the following actions and responsibilities are assigned.

Bureau of Medicine and Surgery

The Chief, Bureau of Medicine and Surgery (CHBUMED) shall manage the hearing conservation program and maintain the program's currency and effectiveness. It must provide audiometric support to all military and civilian personnel who are included in a hearing conservation program, professional and technical assistance to commands responsible for assuring that the hearing of military and civilian personnel is protected, and appropriate professional and technical hearing conservation guidance and assistance to the Chief of Naval Education and Training (CNET).

It must develop guidelines and issue certifications in accordance with OPNAVINST 6260.2 Enclosure (1) for personnel conducting sound level measurements, (2) personnel performing hearing conservation audiometry, (3) audiometric test chambers, (4) audiometers, and (5) all sound level measuring equipment, and it must support a research and development effort in medical aspects of hearing conservation to insure existing technology represents the most advanced state-of-the-art.

Chief of Naval Material

The Chief of Naval Material (CHNAVMAT) shall in coordination with CHBUMED, provide technical assist and and engineering guidance to commands as delineated in OPNAVINST 6260.2 and periodically update to maintain currency and effectiveness. It shall insure, consistent and required military capabilities, that noise abatement is considered, designed, and engineered into all (both existing and future) ships and aircraft, weapons and weapon systems, equipment, materials, supplies, and facilities which are acquired, constructed, or provided through the Naval Material Command; and it shall provide appropriate technical and engineering control methodology guidance and assistance to CNET.

The Chief, Naval Education and Training

The Chief, Naval Education and Training (CNET) shall, with the assistance of CHBUMED and CHNAVMAT incorporate hearing conservation and engineering control guidance information in the curricula of all appropriate training courses. It shall provide specialized hearing conservation and engineering control training and education as required, and serve as the central source for the collection, publication and dissemination of information on specialized hearing conservation and engineering control training courses.

Naval Inspector General

The Naval Inspector General (NAVINSGEN) shall evaluate hearing conservation and engineering control procedures during conduct of the Navy's Occupational Safety and Health Inspection Program (NOSHIP) oversight inspections of activities ashore.

President, Board of Inspection and Survey

The President, Board of Inspection and Survey (PRESINSURV) shall be directly responsible for oversight inspection aspects of shipboard hearing conservation and engineering control compliance. Inspections of fleet units shall be incorporated into existing condition inspection programs.

Commander, Naval Safety Center

The Commander, Naval Safety Center (COMNAVSAFECEN) shall provide program evaluation, as requested, provide program promotion through NAVSAFECEN publications, and review program compliance during the conduct of surveys.

Fleet Commander in Chief

Fleet Commanders in Chief and other major commanders, commanding officers, and officers in charge shall insure that all Navy areas, worksites, and equipment under their cognizance are identified as potentially hazardous and labeled in accordance with OPNAVINST 6260.2 where noise levels are 85 dBA or greater or where impulse or impact noise exceeds a peak sound pressure level of 140 dB. Where necessary, surveys shall be conducted in compliance with the guidance outlined in OPNAVINST 6260.2 enclosure (1). Enclosure (3) of OPNAVINST 6260.2 provides a listing of activities where industrial hygiene assistance may be obtained.

Where a potential noise hazard has been identified, a hearing conservation program shall be instituted in accordance with OPNAVINST 6260.2 and a roster will be maintained on personnel placed in the program. Noise levels will be eliminated or reduced through the use of engineering controls.

Personal hearing protective devices will be provided and used properly by personnel where administrative or engineering controls are infeasible or ineffective. All military civilian personnel whose duties entail exposure to potentially hazardous noise will receive instruction regarding the command occupational noise control and hearing conservation program, the undesirable effects of noise, the proper use and care of hearing protective devices, and the necessity of periodic hearing testing. Emphasis will be placed upon leadership by example as regards the wearing of hearing protective devices. Command policy shall be enforced, including the initiation of disciplinary measures for repeated failure to comply with the requirements of the hearing conservation program.

In addition to the personnel mentioned above, we need to describe the shipboard responsibilities of the Engineer Officer and the work center supervisor.

ENGINEER OFFICER.—OPNAVINST 6260.2 outlines the shipboard program for hearing conservation. Although the medical department representative has primary cognizant over this program there are elements that the engineer officer must monitor and which are subject to periodic review. Periodic surveys must be accomplished to properly identify those areas within the propulsion spaces that fall into the category "Noise Hazardous Area." These areas must be marked and personnel tasked with working in these areas must have available to them and utilize the prescribed aural protective devices. Training and discussion should emphasize the need for wearing these devices and should stress the medical element of hazards to hearing resulting from "non-use." The following paragraphs outline the specific actions to be taken by the engineer officer and subordinates to insure the effectiveness of the command program.

The engineer officer will:

1. Insure that all newly reporting personnel have received a base-line audiogram and that each individual's medical record reflects the results of this examination.
2. Insure that all engineering department personnel receive an annual re-examination by a medical activity.
3. Advise the medical department representative, by memorandum, of personnel by name who are working or stand watches in areas determined to be "high noise areas" and defined in OPNAVINST 6260.2.
4. Arrange for a noise survey to be taken initially by an industrial or IMA activity, and insure that surveys are retaken at least annually.
5. Designate "high noise areas" from the survey and insure that areas are properly marked or labeled with prescribed markings. Advise the medical department of areas so designated and of any changes that may occur.
6. Insure aural protective devices to all personnel tasked to work in designated "high noise areas." These devices will be made available through the medical department for individual fitting and issue. Issue of these devices will be recorded in the individuals' medical records.
7. Insure that sufficient training is provided to operating personnel concerning the hazards and preventive elements of the program, stressing the use of available protective devices.
8. The main propulsion assistant should be designated as the department officer to monitor and assist the engineer officer in all elements of the program.

WORK CENTER SUPERVISOR.—As a work center supervisor you are responsible for ensuring that safety signs are posted in your spaces which are high noise areas, that your personnel are trained and counseled as to the effects of noise pollution, and that they have the proper hearing protection as required for that area.

For additional information on the Hearing Conservation Program refer to OPNAVINST 6260.2.

CHAPTER 9

ENGINEERING CASUALTY CONTROL

This chapter provides general information on engineering casualty control, a phase of damage control. If a review of damage control principles and related information is necessary, see *Basic Military Requirements*, NAVEDTRA 10054 (current edition), *Military Requirements for Petty Officer 3 & 2,* NAVEDTRA 10056 (current edition), *Fireman,* NAVEDTRA 10520 (current edition), and *Naval Ships' Technical Manual,* chapter 079. The mission of engineering casualty control is to maintain all engineering services in a state of maximum readiness and reliability. To carry out this mission, it is necessary for all personnel concerned to know what actions are necessary to prevent, minimize, and correct any effects of operational and battle casualties on the machinery and the electrical and piping installations of their ship.

The primary objective of casualty control is to maintain a ship in such a condition that it will function effectively as a fighting unit. This requires effective maintenance of propulsion machinery, electrical systems, interior and exterior communications, fire control, electronic services, ship control, fire main supply, and of such miscellaneous services as heating, air conditioning, and compressed air. Failure of any of these services will affect a ship's ability to fulfill its primary objective, either directly, by reducing its power, or indirectly, by creating conditions which would lower personnel morale and efficiency.

A secondary objective of casualty control is to minimize personnel casualties and secondary damage to vital machinery.

You can find detailed information on casualty control in the *Engineering Casualty Control Manual*, the *Damage Control Book,* the *Ship's Organization Book,* and the *Ship's Repair Party Manual.* Although these publications vary from ship to ship, they explain the organization and the procedures that must be followed when engineering casualties, damage to the ship, or other emergency conditions occur.

FACTORS INFLUENCING CASUALTY CONTROL

The basic factors influencing the effectiveness of engineering casualty control are much broader than the immediate actions taken at the time of the casualty. Engineering casualty control efficiency is obtained through a combination of sound design, careful inspection, thorough plant maintenance (including preventive maintenance), and effective personnel organization and training. CASUALTY PREVENTION IS THE MOST EFFECTIVE FORM OF CASUALTY CONTROL.

DESIGN

Design influences the effectiveness of casualty control in two ways: (1) the elimination of weaknesses which may lead to material failure and (2) the installation of alternate or standby equipment for supplying vital services in the event of a casualty to the primary equipment. Both of these factors are considered in the design of naval ships. Each individual plant aboard ship is equipped with duplicate vital auxiliaries, loop systems, and cross connections. All complete propulsion plants are designed to operate as isolated units (split-plant design).

CASUALTY CONTROL COMMUNICATIONS

Casualty control communications is extremely important to the operation and organization of the ship. Without adequate and proper means of communication between the different units, the whole organization of casualty control will fail in its primary objective.

To ensure that sufficient means of communications are available, several different systems are installed aboard ship. The normal means of communications are the battle telephone circuits (sound powered), interstation 2-way systems (intercoms), ship service telephones, ship's loud speaker (1-MC), and voice tubes. Messengers are also used in some situations when other methods of communications are not available or when written reports are required.

The transmission of correct information regarding a casualty and the speed with which the report is made are essential to be of value in any method of communication.

It is also essential that control of all communication circuits be established by the controlling station. The circuits must never be allowed to get out of control, because of "cross-talk" caused by more than one station operating at the same time and each assuming that it has the priority message. Casualty control communication must be incorporated into casualty control training, since prompt action to notify the control station or engineering control of a casualty must be taken to prevent the development of other casualties which could be more serious than the original casualty.

INSPECTION AND MAINTENANCE

Inspection and maintenance are vital to successful casualty control, since they minimize the occurrence of casualties due to material failures. Continuous and detailed inspections are necessary not only to discover partly damaged parts which may fail at a critical time, but also to eliminate any underlying conditions which may lead to early failure (maladjustment, improper lubrication, corrosion, erosion, and other causes of machinery damage). Particular and continuous attention must be paid to symptoms of malfunctioning, such as unusual noises, vibrations, abnormal temperatures, abnormal pressures, and abnormal operating speeds.

Operating personnel should thoroughly familiarize themselves with the specific temperatures, pressures, and operating speeds required for the normal operation of equipment, in order to detect all departures from normal operation.

When a gage, or other instrument recording the operating conditions of machinery, gives an abnormal reading, the cause must be fully investigated. A spare instrument, or a calibration test, will quickly indicate whether or not the abnormal reading is due to instrument error. Any other cause must be traced to its source.

Because of the safety factor commonly incorporated in pumps and similar equipment, considerable loss of capacity can occur before any external evidence is readily apparent. Changes in the operating speeds (from those normal for the existing load) of pressure-governor-controlled equipment should be viewed with suspicion. Variations from normal pressures, lubricating oil temperatures, and system pressures indicate either inefficient operation 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 that other similar failures might occur. Prompt inspection will prevent a series of repeated casualties.

Strict attention must be paid to the proper lubrication of all equipment. Frequent inspections and samplings must be made to ensure that the correct quantity of the proper lubricant is in the unit. Lube oil samples must be taken daily on all operating auxiliaries. Lube oil samples should be allowed to stand long enough for any water to settle. Where auxiliaries have been idle for several hours, particularly overnight, a sufficient sample should be drained from the lowest part of the oil sump to remove all settled water. Replenishment with fresh oil to the normal level should be included in this routine.

The presence of saltwater in the oil can be detected by running a standard chloride test. A sample of sufficient size for test purposes can be obtained by adding distilled water to the oil sample, shaking vigorously, and then allowing the water to settle before draining off the test sample. Because of its corrosive effects, saltwater in the lubricating oil is far more dangerous to a unit than an equal quantity of freshwater. Saltwater in units containing oil-lubricated ball bearings is particularly harmful.

TRAINING

Casualty control training must be a continuous step-by-step procedure and should provide for refresher drills. Any realistic simulation of casualties must be preceded by adequate preparation. You and your work center personnel must learn to understand fully the consequences of any error which may be made in handling real or simulated casualties.

The majority of all engineering plant casualties can be attributed to a lack of knowledge of the correct procedures on the part of the watch station personnel. Often a relatively simple problem, if allowed to compound itself, could lead, ultimately, to the disabling of the ship. The causes of ineffective casualty control and their prevention are listed as follows:

1. Lack of positive control. The Engineering Officer of the Watch (EOOW) must maintain positive control of every situation that arises and must possess thorough knowledge of the correct procedures and systems operation.
2. Lack of effective communications. Communications throughout the engineering plant must be maintained at all times. The repeat back technique for watchstanders is the only means of ensuring that communications are received and understood.
3. Lack of systems knowledge. Watch personnel are frequently shallow in their depth of systems knowledge and approach to casualty control. Watch sections must be familiar with the operation and theory of all vital engineering systems.
4. Lack of casualty control assistance. Off-watch personnel are not called to assist in casualty control follow-up actions with the result that watchstanders are unable to satisfactorily deal with recovering from a casualty. Off-watch personnel must be called to provide requisite expertise and augment assigned watchstanders performing restoration actions.

In the past, the primary emphasis in casualty control training has been placed on speed. However, with the development and implementation of the Engineering Operational Casualty Control (EOCC) portion of the Engineering Operational Sequence System (EOSS), a more methodical and organized approach to casualty control has resulted in increased control, less disabling of a plant, and an increase in the overall safety to the plant and personnel.

To ensure maximum engineering department operational readiness, a ship must be self sufficient in the conduct of propulsion plant casualty control drills. The management required for such drills involves the establishment of the Engineering Casualty Control Evaluation Team (ECCET) and the preliminary administrative support for the training program.

Engineering Casualty Control Evaluation Team (ECCET)

An ECCET should be developed for each underway watch section, and a sufficient number of personnel should be assigned to evaluate each watch station during the drills.

The engineer officer must ensure the development of an accurate, comprehensive drill package adequate to exercise the engineering department in all phases of casualty control procedures. The drill package should contain a complete file of drill scenarios and drill cards for each type of casualty that could reasonably occur to the propulsion plant. The scenarios should contain the drill title, scenario number (if assigned), a general description of the casualty, the method of imposing the drill, the cause (several possible causes should be listed) and estimated time of repair (ETR), cautions to prevent personnel hazards or machinery damage, and any simulations to be used in the drill. The drill cards must give the correct procedure to be followed by each watch team member in the proper sequence for the drill. The purpose of the drill cards is to give the ECCET members ready reference to the proper procedures to be followed. The engineer officer must ensure that adequate research is done to ensure the accuracy of each scenario and pertinent drill cards. EOCC, if installed, should be the prime information source. The main propulsion assistant (MPA) should have custody of a master drill package, with appropriate copies of applicable drill scenarios and drill cards for each space.

The planning and scheduling of casualty control drills should receive equal priority with other training evolutions that are conducted during normal working hours. When a specified time for conducting casualty control drills is authorized by the commanding officer, the engineer officer must prepare a drill plan which provides for the training desired. Careful preplanning and sequencing of events is mandatory.

After the proposed drill plan is approved by the commanding officer, the designated ECCET personnel meet and make sure that each member of the team understands the procedures and the sequencing of events. In preparing the drill plan, consideration is given to the following:

1. General condition of the engineering plant.
2. Machinery and safety devices out of commission.
3. Length of time set aside for drills.
4. State of training of the watch section.
5. Power to be provided to vital circuits.

Within the constraints of the items listed above, first priority on drill selection is given to boiler casualty drills and propulsion space fire drills in that these drills represent the greatest danger and involve the largest number of propulsion plant watch team personnel. Second priority is given to lube oil system casualties because of the inherent danger to main and auxiliary equipments that these casualties represent. Third priority is given to other main engine casualties. In selecting drills, the engineer officer must give emphasis to the development of watch team proficiency in handling priority one type casualties.

Normally, ECCET members arrive on station shortly before the drills commence and ensure that communications are established throughout the plant. With the officer of the deck's (OOD's) permission, the drill initiator imposes a casualty in accordance with the drill plan. Within the boundaries of safety to personnel and equipment, drills are conducted as realistically as possible and simulations are kept to an absolute minimum. Any time a hazardous situation develops, ECCET members assist the watch section in restoring the plant to the proper operating parameters. Additionally, the ECCET members complete a drill critique form during the course of the drill.

As soon as possible following the drill, a critique is conducted. It is attended by personnel of the applicable watch section, the ECCET, and the engineer officer. The ECCET leader gives the finding for the drill and, in the case of unsatisfactory drills, provides the reasons for that finding. All other ECCET members then read their drill critique form. Drills are evaluated as satisfactory or unsatisfactory by the ECCET leader, based on a review of the critique sheets prior to the critique. The following deficiencies form a basis for a finding of unsatisfactory for a drill:

1. Loss of plant control by the EOOW or space supervisor when he is either unaware of the status of the plant, or unable to restore the plant to a normal operating condition utilizing EOSS/EOCC or other promulgated casualty control procedures.
2. Safety violations which cause a hazard to personnel or may result in serious machinery derangement.
3. Significant procedural deficiencies which indicate a lack of knowledge of the proper procedures to be followed in correcting a casualty.

CORRECTION AND PREVENTION 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 propulsion power, steering, and electrical power generation and distribution. If casualties associated with these functions are allowed to spread, they may lead to serious damage to the engineering installation, a damage which often cannot be repaired without loss of the ship's operating availability. Where possible risk of permanent damage exists, the commanding officer has the responsibility for deciding whether or not to continue the operation of the equipment under casualty conditions. The operation of equipment under casualty control 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.

Whenever there is no probability of greater risk, the proper procedure is to secure the malfunctioning unit as quickly as possible even though considerable disturbance to the ship's operations 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 irreparable damage and possible loss of the ship may result. War experience has shown that the cross-connecting of an intact system with a partly damaged one should be delayed until it is certain that such action will not jeopardize the intact system. 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 predictable casualties.

PHASES OF CASUALTY CONTROL

The handling of any casualty can usually be divided into three phases: (1) limitation of the effects of the damage, (2) emergency restoration, and (3) complete repair.

The first phase is concerned with the immediate control of the casualty so as to prevent further damage to the unit affected and to prevent the casualty from spreading.

The second phase consists of restoring, as far as practicable, the services which were interrupted as a result of the casualty. For many casualties, the completion of this phase eliminates all other operational handicaps, except for the temporary loss of the standby units-which lessens the ship's ability to withstand additional failures. If no damage to machinery occurred, this phase usually completes this phase of casualty control.

The third phase of casualty control consists of making repairs which completely restore an installation to its original condition.

SPLIT-PLANT OPERATION

In ships having two or more shafts, a fundamental principle of engineering casualty control is SPLIT-PLANT operation. The purpose of the split-plant design is to minimize damage that might result from any one hit.

Most naval ships built primarily as warships have at least two engineering plants. The larger combatant ships have four individual engineering plants.

Split-plant operation means separating the engines, pumps, and other machinery so that two or more engineering plants are available, each complete in itself. Each main engine installation is equipped with its own piping systems and other auxiliaries. Each engineering plant operates its own propeller shaft. If one engineering plant were to be put out of action by an explosion, shellfire, or flooding, the other plant could continue to drive the ship ahead, though at somewhat reduced speed.

Split-plant operation is not an absolute insurance against damage that might immobilize the entire engineering plant, but it does reduce the chances of such a casualty and it prevents damage to one plant from being transmitted to, or seriously affect the operation of, the other plant or plants. Split-plant operation is the first step in the PREVENTION of major engineering casualties.

The fuel oil system is generally so arranged that by means of fuel oil transfer pumps, suction can be taken from any fuel oil tank on the ship and the oil pumped to any other fuel oil tank. Fuel oil service pumps are used to supply oil from the service tanks to the main engines. In split-plant operations the forward fuel oil service pumps of a ship are lined up with the forward service tanks, and the after service pumps are lined up with the after service tanks. The cross-connection valves in the fuel oil transfer line are always closed except when oil is being transferred.

Although geared diesel propulsion plants are designed for split-plant operation only, some of the auxiliary and main systems maybe run cross-connected or split. Among these are the starting air systems, the cooling water systems, the firemain systems, and, in some plants, the fuel and lube oil systems.

In diesel-electric installations the diesel elements are designed for split operation, but generator elements can be run either split or cross-connected.

LOCKING MAIN SHAFT

An engineering casualty may affect the rotation of the main shaft and cause further damage. In such cases, the main shaft should be locked until necessary repairs can be made, since, except at very low speeds, movement of the ship through the water will cause the shaft to turn, whether the ship is proceeding by its own power or being towed.

There are no standard procedures for locking a main shaft which are applicable to all types of diesel-driven ships. On ships that have main reduction gears, shaft locking by means of the jacking gear is permissible, provided that the jacking gear has been designed for this purpose (as indicated, by the manufacturer's instructions) or when such action is approved by NAVSEA. Some ships are provided with brakes that are used for holding the shaft stationary. When no provisions have been made for locking the main shaft, it is usually possible to arrange a jury rig (preferably at a flanged coupling) which will hold the shaft. As a precautionary measure, jury rigs should be made in advance of an actual need for locking a shaft. On diesel-electric drive ships, no attempt should be made to hold the shaft stationary by energizing the electrical propulsion circuits.

EMERGENCY PROCEDURES

Under certain circumstances you may receive the order to light off additional engines. When time will not permit following normal routine procedures, emergency procedures may have to be used. Since procedures differ, depending on the installation, you must be familiar with the procedures established for your ship.

These emergency procedures are listed in the *Engineering Casualty Control Manual* for your ship. They are issued by the type commander. Upon receipt, manuals are modified to fit the individual installation. It is the responsibility of your ship's engineer officer to establish the step-by-step emergency procedures and the necessary checklists.

ENGINEROOM CASUALTIES

The type commander for each class ship formulates the engineering casualty procedures which are applicable to a specific type of engineering plant.

In the event of a casualty to a component of the propulsion plant, the principal objective is the prevention of additional or major casualties. Where practicable, the propulsion plant must be kept in operation by means of standby pumps, auxiliary machinery, and piping systems. The important action to be taken is to prevent minor casualties from becoming major casualties, even if it means suspending the operation of the propulsion plant. It is better to stop the main engines for a few minutes than to risk putting them completely out of commission.

When a casualty occurs, notify immediately the EOOW or the petty officer of the watch, who will in turn notify the OOD and the 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 the probable duration of the casualty.

DIESEL ENGINE CASUALTIES

The Engineman's duties concerning engineering casualties and their control depend upon the type of ship-which may be anything from a PT boat to a carrier. An Engineman operates engines of various sizes, made by various manufacturers, and intended for different types of services.

Detailed information of diesel engine casualty control procedures must be obtained from the manufacturers' instructions, the pertinent type commander's instructions, and the ship's *Engineering Casualty Control Manual.*

Some examples of the types of engineering casualties that may occur, and the action to be taken are given below. The observance of all necessary safety precautions is essential in all casualty control procedures.

BROKEN INJECTION TIP

1. Cut out the faulty injector.
2. Notify the engineer officer and the bridge of the casualty. Request permission to secure the engine for repairs.
3. After permission has been obtained, secure the engine, remove the injector and replace it with the spare, following the procedures outlined in the appropriate maintenance manual.
4. After repairs are completed, test the engine. When it is operating properly, report to the engineer officer and the bridge.

BROKEN CYLINDER LINER

1. Secure the engine.
2. Report to the engineer officer and the bridge. Request permission to proceed with repairs.
3. When permission is granted, remove the head and piston; pull the broken liner and replace

it with the spare liner. Follow the procedure as outlined in the engine maintenance manual.

4. Make the necessary reports.

FAILED MAIN ENGINE LUBE OIL PRESSURE

1. Secure the engine immediately.

2. Notify the engineer officer and the bridge.

3. Check the sump oil level, the piping, the filters, the strainers, and the lube oil pump capacity. Make repairs.

4. After repairs have been completed, notify the engineer officer and the bridge.

WATER IN AN ENGINE CYLINDER, CRANKCASE, OR AIR PORTS

1. Notify the OOD and the engineer officer and keep them informed.

2. Do not allow the engine to be started until the cause of the casualty has been determined and corrected.

3. Check the cylinders by jacking over with test cocks open.

4. Put pressure test on freshwater system and conduct visual inspection of the units.

5. Replace part or parts, as necessary.

6. Start the lube oil purifier to remove water from the lubricating oil.

7. After repairs have been completed, test the engine and place it back in commission.

INOPERATIVE SPEED GOVERNOR

1. Control the engine manually, if possible.

2. Notify the engineer officer and the bridge, and request permission to secure the engine for repairs.

3. When permission has been obtained, check the governor control mechanism.

4. Check the linkage for binding or sticking.

5. Check the lubrication; flush and refill with proper oil.

6. Check setting of needle valve.

7. Make repairs. When they are completed, start the engine and check its operation. When it is operating properly, notify the engineer officer and the bridge.

LOST FUEL OIL PRESSURE

1. Notify the bridge.

2. Check the entire fuel system, including strainers, filters, and valves. Check the amount of fuel in service tanks, fuel lines, pumps, and relief valves until the trouble is found.

3. Make necessary repairs and test the engine.

4. Place the engine back in commission when the troubles are corrected.

ABNORMALLY HIGH LUBE OIL TEMPERATURE

1. Check the lube oil pressure.

2. Check the saltwater dump discharge pressure and the temperature of the cooling water.

3. Check the freshwater level in the expansion tank and the temperature of the freshwater.

4. Check the sea suction and the overboard valves.

5. Vent the freshwater and the saltwater pumps.

6. Check the operation of the thermostat control valve to the lube oil and freshwater heat exchanger.

7. Report any trouble found to the engineer officer and the bridge. Request permission to secure the engine for repairs.

8. When permission is received, make repairs.

9. After repairs are completed, check the engine and, after it is operating properly, report to the engineer officer and the bridge.

ENGINE COOLING WATER TEMPERATURE ABOVE THE ALLOWED LIMIT

1. Notify the bridge.

2. Reduce the load and the speed of the engine.

3. Check the freshwater level in the expansion tank.

4. Check the saltwater discharge pressure.

5. Check the sea suction and the discharge valves.

6. Vent the freshwater and the saltwater pumps.

7. Check the setting and operation of the temperature regulating valve.

8. If conditions warrant securing the engine at any time, secure and notify the bridge and the engineer officer.

9. Make repairs, test out the engine, and, if it is operating properly, notify the engineer officer and the bridge.

FUEL OIL CASUALTIES

In addition to casualties which may involve parts of the fuel oil system within the engine, other casualties may occur which involve the system outside of the engine. Examples of some of the possible casualties, along with the action to be taken follow:

WATER IN DIESEL FUEL OIL SERVICE (DAY) TANK

1. Shift fuel oil suction.
2. Notify the engineer officer and the bridge of the casualty.
3. Drain the water from all filters, strainers, and lines.
4. Open all test cocks on the engine, and turn the engine over until assured that the system is free of water.
5. Close the test cock. Start the engine. Check its operation. If operation is normal, notify the engineer officer and the bridge that the engine is ready for normal operation.
6. Strip or drain the contaminated service tank and refill with clean fuel using the fuel oil purifier.

INOPERATIVE DIESEL FUEL OIL TRANSFER PUMP

1. Line up the diesel purifier to supply the tank as quickly as possible.
2. Notify the engineer officer of the casualty.
3. In an emergency, line up and use the hand-operated pump in order to continue operation.
4. At the earliest possible time, inspect and repair the fuel oil transfer pump.
5. Report the results of the investigation and repairs to the engineer officer.

HYDRAULIC COUPLING CASUALTIES

Coupling casualties vary with each installation. The following examples, and the action to be taken, are applicable to some Fairbanks-Morse marine installations.

FAILURE OF THE MAIN LUBE OIL PUMP

1. Start the standby pump or the lube oil transfer pump and cut in on the line.
2. Cross-connect the twin hydraulic coupling systems.
3. Notify the engineer officer and the bridge of the casualty and the emergency measures taken.
4. At the earliest possible time, repair the hydraulic lube oil pump.
5. Report the repairs completed to the engineer officer and the bridge, and request permission of the engineer officer to start the pumps.

INOPERATIVE PROPELLER SHAFT PNEUMATIC BRAKE

1. Report the casualty to the bridge and the engineer officer.
2. Check the air pressure to the brake.
3. Check the air reducing valve to the brake.
4. Check the electrical and pressure control switches to the air control valve.
5. If the trouble is not determined and the use of the engine is required, do the following:

   a. Secure the air to the brake system until proper inspection of the brake shoes and expansion core can be made.
   b. Notify the bridge and the engineer officer that the engine is being operated without the brake, and that the throttle alone is being used for control.
   c. Use extreme caution during the operation.
   d. At the earliest possible time, inspect and repair the brake.
   e. Report the repairs to the engineer officer.

INOPERATIVE COUPLING LUBE OIL REGULATING VALVE

1. Maintain the correct operating pressure by manually operating the clutch dump valve.
2. Report to the engineer officer and the bridge. Request permission to secure the engine to effect repairs.

3. When permission is granted, replace or repair the valve.
4. Test for proper operation.
5. If the valve is operating properly, report to the engineer officer and the bridge.

OVERHEATING COUPLING

1. Check the system to determine the cause of overheating.
2. Regulate the valves manually to maintain proper operating temperatures.
3. Notify the engineer officer and the bridge. If it is necessary to secure the engine to effect repairs, request permission.
4. When permission is granted, secure the engine and effect repairs.
5. Upon completion of repairs, notify the engineer officer and the bridge.

COUPLING THROWING OIL

1. Check the system. Attempt to repair the leak.
2. Report to the engineer officer and the bridge. If the leak is not repaired, request permission to secure the engine for repairs.
3. When permission is granted, secure the engine, conduct an investigation, and make necessary repairs.
4. Upon completion of repairs, test the coupling.
5. Report to the engineer officer and the bridge.

HEAT EXCHANGER CASUALTIES

Following are the procedures to be followed under various conditions of operation when diesel engine heat exchanger casualties occur:

UNDER NORMAL STEAMING CONDITIONS

1. Notify the engineer officer and the OOD, and request permission to secure the engine.
2. When permission is granted, secure the engine.
3. Secure both the saltwater inlet and outlet valves to the heat exchanger.
4. Remove the visual inspection plate on the exchanger. Plug the expansion tank vent, and apply pressure to the freshwater side of the system by opening the valve from the ship's freshwater supply system, and check for leaks.
5. Upon detection of the leak, plug the tubes or install another core.
6. Upon completion of the repairs, notify the engineer officer.

DURING HOSTILITIES, WITH ACTION PROBABLE

1. Notify the engineer officer and the OOD, and request permission to slow the engine and increase speed on the other engine to maintain the speed required.
2. Reduce the saltwater cooling pressure to the heat exchanger by using manual control.
3. Keep a constant watch on the supply of freshwater in the expansion tank; keep the tank refilled from the ship's service freshwater system, to replace water lost through the leak. Observe all gages constantly for normal operating pressures and temperatures. Keep the engineer officer informed of operating conditions.
4. At the earliest possible time, make the necessary repairs.

OTHER PROPULSION PLANT CASUALTIES

Examples of other casualties which may affect propulsion plant operation are described below.

OVERHEATING MAIN SHAFT BEARINGS

Hot bearings may generally be traced to one of the following causes:

1. Insufficient lubrication.
2. Defective oil ring.
3. Grit or dirt in the oil.
4. Bearing out of line.
5. Bearing improperly fitted.
6. Poor condition of bearing or journal surface.

If the trouble is due to insufficient lubrication and is discovered before the bearing metal has wiped, an abundant supply of oil should gradually bring the bearing back to its normal operating temperature.

A defective oil ring should be repaired or replaced.

Should the trouble be caused by grit, dirt, or foreign matter in the bearing, the oil should be renewed. The new oil may flush out the impurities in the bearing surfaces sufficiently to permit continued operation.

If the main shaft bearing is out of line or improperly fitted, or if the bearing or journal is not in proper condition, only temporary relief can be obtained from use of the various means suggested above. The most effective treatment will probably be the operation of the main engines at low or moderate speeds until such time as the proper adjustments or repairs can be made.

Abnormal temperatures of a bearing can be lowered by slowing down the main shaft and thus decreasing the amount of friction in the bearing. If the trouble has reached an advanced stage, it may be necessary to stop the main shaft. In an emergency, cold water may be used on a bearing to reduce the temperature so that it will be within safe operating limits; it must be remembered, however, that cold water will cause contraction of the bearing. Also, care must be taken to see that water does not contaminate the bearing oil.

Once a bearing has wiped, it should be reconditioned. If it has wiped out slightly, it can probably be scraped to a good bearing surface and restored to service. If badly wiped or burned out, the bearing will require replacement. Inspect the journal and remove any high spots by lapping the journal.

UNUSUAL NOISE IN REDUCTION GEAR

This information applies to diesel-driven ships that have main reduction gears. The action taken will depend upon the two following conditions:

1. When noise and conditions indicate that tooth failure is not probable:

   a. Slow the engine immediately and stop it if the noise persists.

   b. Check the oil discharge pressure, the temperature of the bearing, and the operation of oil sprays and strainers. Look for the presence of babbitt or other foreign matter.

2. When there is a loud or roaring noise indicating gear tooth damage:

   a. Stop the engine and check the shaft immediately.

   b. Lock the main shaft in accordance with EOSS/EOCC procedures or the manufacturer's instruction.

   c. Make a preliminary investigation of the gear teeth and other parts of the main reduction gear.

PROPULSION SHAFT VIBRATES EXCESSIVELY

When the propulsion shaft vibrates excessively, take the following actions:

1. Slow the shaft. If the vibration continues, stop and lock the shaft.
2. Investigate to determine the cause of the vibration. Take necessary action to correct the cause of the vibration.

Frequently, the circumstances under which a ship is operating should be considered when trying to determine the probable cause for excessive vibration. For example, if the ship is in shallow water or close to a beach, the vibration may be caused by the propeller striking ground.

ELECTRICAL CASUALTY CONTROL

Since Enginemen and Electrician's Mates are assigned duties in operating diesel-driven emergency generating plants on steam-driven ships, and all electrical generating plants on diesel-driven ships, they must have a general knowledge of the purpose of electric generating plants, their operation under various conditions, and the types of casualties that will interfere with, or disrupt, the normal operation of an engineering plant.

THE ELECTRICAL PLANT

The ship's power and lighting plant consists of generators, switchboards, power panels, cables, circuit breakers, and other equipment necessary for the generation, distribution, and control of power supplies to electrically driven auxiliaries, lighting, interior communication, electronics equipment, and other electrically powered devices. In designing the electric plant, every effort is made to obtain the greatest reliability and continuity of service possible under casualty conditions.

The distribution system forms the vital connection between the generators and the equipment which uses electric power. The distribution of electrical power is generally done through either the ship's service or the emergency switchboards. Electrical power distribution may also be done through a casualty power circuit rigged from either of these switchboards.

The general arrangement of the ship's service system is such that any faulty circuit will be cut out automatically, without interruption of power supply to other circuits. This is done through the operation of protective devices. If the ship's service generators fail, the emergency generator is automatically placed in operation for battle functions. The emergency switchboard can supply power to all parts of the ship; however, all unnecessary circuits must be stripped from the board when the emergency generator is set up in automatic to supply emergency power to vital equipment. If this is not done, the generator will be overloaded and the breakers will trip out or the diesel engine will stall.

Protection against loss of power on a ship with ship's service, emergency, and casualty power distribution systems is described below:

1. FAILURE OF ONE SHIP'S SERVICE GENERATING PLANT. The load is transferred, by the Electrician's Mate, to the other ship's service generating plant. Care must be taken to prevent overloading the generating plant that takes over the load.

2. CIRCUIT OR SWITCHBOARD FAILURE. Vital loads are transferred to an alternate feeder and source of ship's service power by means of a transfer switch on the control panel.

3. FAILURE OF BOTH NORMAL AND ALTERNATE POWER SUPPLY. Certain vital equipment are shifted to an emergency feeder which receives power from the emergency switchboard.

4. FAILURE OF THE SHIP'S SERVICE AND EMERGENCY CIRCUITS. Temporary circuits are rigged with the casualty power cables from any live switchboard to supply power to vital circuits.

EMERGENCY POWER SYSTEM

The purpose of the emergency power system is to furnish an immediate, automatic source of electric power to a limited number of selected vital circuits. It includes one or more diesel-driven emergency generators, the emergency switchboards, and a distribution system, which is separate from the ship's service electric plant and distribution system. Emergency feeders run from the emergency switchboards to at least one and usually to two different ship's service switchboards. Emergency power feeders for certain vital auxiliaries are also run to control panels. The emergency power system, with the use of transformers, is also used for furnishing emergency lighting.

Whenever practical, emergency generators and switchboards are installed above the waterline, to minimize danger from flooding. Also, the emergency plant is installed as far away as practical from the ship's service plant, to avoid both plants being put out of action by battle damage.

On most ships, the emergency generators do not have the same capacity as the ship's service plants. Therefore, care must be taken to prevent overloading the emergency generator, which in turn will overload the diesel engine.

CASUALTY POWER SYSTEM

The casualty power system is used to supply emergency power for steering gear, fireroom and engineroom auxiliaries, fire pumps, drainage pumps, communications equipment, and other vital machinery needed to keep the ship afloat or to get it out of a danger area.

The casualty power system is a simple electrical distribution system used to maintain a source of electrical supply for the most vital machinery and equipment needed to keep the ship afloat and functioning. This casualty power system is intended to supply power during emergencies ONLY. The system is purposely kept simple so that it can be rigged quickly and with a minimum chance of error; but, the very simplicity of its design limits the extent of its use.

Sources of supply for casualty power use are provided at each ship's service switchboard and at each emergency switchboard. They consist of casualty power terminals that are connected to the bus bars through circuit breakers. Some ships have small diesel-driven generators which are designed for casualty power use only; these generators are very small and have a minimum of control equipment. Casualty power terminals are installed on power panels that feed equipment designated to receive casualty power; these terminals may also be used as a source of supply to the casualty power system if power from the permanent feeders to the panels is still available.

The casualty power system is either a.c. or d.c., as appropriate for the particular installation. Only the a.c. system is described here. The d.c. system is similar to the a.c. system, but uses different types of cables and fittings.

The portable, thermoplastic-covered or neoprene-covered cables for the a.c. casualty power system are stowed in racks in convenient locations throughout the ship. Each cable contains three leads (conductors), colored black, white, and red. This same color code is used in all three-wire power circuits throughout the ship.

On smaller ships, the bulkhead terminals for the casualty power system are arranged so as to allow for one horizontal run of the portable cable along the main deck, and generally, if possible, inside the deck house. On larger ships, generally there are terminals for two horizontal runs of cable, one port and one starboard. These are located on the second deck. The terminals extend through the bulkhead and project from it on each side, and do not impair the water-tight integrity of the compartments in which they are installed. The cable ends are inserted into the holes that are provided around the outer rim (curved surface) of the terminal. Both the rim and the face of each terminal have three groups of three holes each, into which fit the square-shanked, insulated wrenches that are used to secure the cables in the terminal. Two square-shanked wrenches are provided in the rack mounted on the bulkhead at each point where they will be required. These wrenches MUST be kept in the racks at all times when they are not actually in use.

The riser terminals for the casualty power system are similar to the bulkhead terminals, except that they are connected to other riser terminals by vertical runs of permanently installed, armored cable. The risers and the riser terminals carry the casualty power from the level of the generators to the main deck and second deck levels.

Portable switches are sometimes provided on the bulkheads, near the cable racks. These are simple ON-OFF switches which have special holes for use with the portable cables.

The terminals and the cables in an a.c. casualty power system are marked so that they can be identified easily when the system is being connected. The faces of the terminals are marked A, B, and C, and the three leads on each cable are colored black, white, and red, respectively. When connecting the cables to the terminals, you connect the black lead to A, the white lead to B, and the red lead to C. Since the letters and the colors cannot be seen in darkness, the terminals are further identified by molded knobs in the A, B, and C areas—one knob for A, two for B, and three for C. The cable leads are identified by servings of twine—one for black, two for white, and three for red. Each serving of twine is about 1 inch wide. Thus each lead and its corresponding position in the terminal can be identified merely by feeling the leads and matching the number of pieces of twine on each lead with the number of raised knobs on the terminal. (In older ships, the casualty power fittings may still have identifying V-shaped notches in the outer edge instead of raised knobs.)

CAUTION: When connecting a run of casualty power cable, ALWAYS CONNECT FROM THE LOAD BACK TO THE POWER SUPPLY! By rigging the system in this manner, you will avoid working with an energized cable. Also be SURE to shut off the normal supply to any power panel before you connect the casualty power cable to the terminals on the power panel.

EMERGENCY FIRE PUMPS

Most ships have electric-driven fire pumps located outside the engineering spaces. These pumps furnish water under presssure to their own piping system or to the ship's firemain. Provisions are made for different sources of electrical power to these pumps: normal and alternate supply from the ship's service generators, emergency supply from the diesel-driven emergency generators, and the casualty power system itself.

Many ships, such as carriers, tankers, and tugs, have independent diesel-driven fire pumps. If ship's pumps and firemain are damaged, these diesel-driven pumps can be used to furnish large amounts of water for firefighting purposes.

LIGHTING SYSTEM

On ships using a.c. generators, the ship's service and emergency lighting systems are energized from the generator and distribution switchboards through a bank of transformers. These transformers supply power to the lighting system through the lighting distribution panels.

Lighting throughout the machinery spaces is supplied from the normal switchboard for the compartments involved, with some lights in each space supplied from the alternate switchboard. A few lights in each compartment are supplied through automatic bus transfer equipment from circuits originating at the emergency switchboards. A few lights in each compartment are supplied through automatic bus transfer equipment from circuits originating at the emergency switchboards.

Automatic type hand lanterns are provided to supply an instantaneous source of illumination, in the event of complete failure of the ship's service and emergency lighting systems. These relay-operated hand lanterns are installed at vital stations. In addition to these, nonautomatic type hand lanterns are also installed at these stations.

An EN1 or ENC in charge of an engineering space has the supervisory responsibility to see that the hand lanterns, especially the automatic type, are not removed except for actual intended use, and that hand lanterns are available for use at all times. Although the Electrician's Mates have the responsibility for the maintenance of the hand battle lanterns, it is the duty of the petty officer in charge of the space to see that personnel do not remove the lanterns or use them for unauthorized purposes.

The EN1 or ENC should also ensure that personnel have an adequate number or flashlights available for use should all the lights in an engineering space go out.

ELECTRICAL POWER PANELS AND TERMINALS

Power panels are supplied with two or three sources of power—normal, alternate, and emergency. These panels are equipped with circuit breakers or switches which permit the transfer from one source to another in the event of a casualty.

Regular electrical outlets are installed throughout the engineering spaces for use with small portable tools; multipurpose outlets are installed in selected locations for use with portable submersible pumps and portable welding sets. These outlets are located so that it is possible to use two portable submersible pumps in any watertight compartment. Portable triple outlet extension cables are provided to permit the concentration of all submersible pumps in one area. An adapter provided with these extension cables permits connection of the submersible pumps to the casualty power terminals. All this equipment is stowed in the damage control lockers.

Engineroom personnel should be trained in the emergency use and operation of submersible pumps as well as other damage control equipment. They should know the location of both normal and emergency power outlets in their spaces, and should understand the different methods used to supply electrical power for operating submersible pumps in the engineroom.

Engineroom personnel should also be familiar with sources of electrical power provided to the different power panels in an engineroom. During engineering casualty control drills and during actual emergencies, the Enginemen should be able to shift from one source of electrical supply to another.

BATTLE CASUALTIES

As an EN1 or ENC you will be responsible for handling battle casualties, you will have to know the location of isolating and cross-connecting valves, and recognize which of the valves are remotely controlled. As a general rule, personnel safety will be your first consideration in handling casualties.

Effective control of battle casualties depends on a good knowledge of the principal engineering piping systems and related equipment. This information may be found in the ship's *Engineering Casualty Control Manual*, in the *Damage Control* Book, in the plans of the principle engineering systems, and in other applicable sources located aboard ship.

In the event of a battle casualty to an engineering piping system, the damaged section must be isolated and the system should be cross-connected, when possible. Emergency or alternate equipment should be used, when provided, to restore service to vital systems. Whenever feasible, emergency repairs should be made and the system restored to normal operation. Special precautions should be taken to prevent additional damage which may result from any original casualty.

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Assignment Questions

Information: The text pages that you are to study are provided at the beginning of the assignment questions.

Assignment 1

Administration, Supervision, and Training

Textbook Assignment: Engineman l&C; NAVEDTRA 10543-E1, Pages 1-1 through 2-12

In this course you will demonstrate that learning has taken place by correctly answering training items. The mere physical act of indicating a choice on an answer sheet is not in itself important; it is the mental achievement, in whatever form it may take, prior to the physical act that is important and toward which correspondence course learning objectives are directed. The selection of the correct choice for a correspondence course training item indicates that you have fulfilled, at least in part, the stated objective(s).

The accomplishment of certain objectives, for example, a physical act such as drafting a memo, cannot readily be determined by means of objective type correspondence course items; however, you can demonstrate by means of answers to training items that you have acquired the requisite knowledge to perform the physical act. The accomplishment of certain other learning objectives, for example, the mental acts of comparing, recognizing, evaluating, choosing, selecting, etc., may be readily demonstrated in a correspondence course by indicating the correct answers to training items.

The comprehensive objective for this course has already been given. It states the purpose of the course in terms of what you will be able to do as you complete the course.

The detailed objectives in' each assignment state what you should accomplish as you progress through the course. They may appear singly or in clusters of closely related objectives, as appropriate; they are followed by items which will enable you to indicate your accomplishment.

All objectives in this course are learning objectives and items are teaching items. They point out important things, they assist in learning, and they should enable you to do a better job for the Navy.

This self-study course is only one part of the total Navy training program; by its very nature it can take you only part of the way to a training goal. Practical experience, schools, selected reading, and the desire to accomplish are also necessary to round out a fully meaningful training program.

Learning Objective: Recognize some of the increased responsibilities related to advancement and point out some of the practices that should be followed when training personnel.

- Questions 1-1 and 1-2 are to be judged True or False.

1-1. The successful accomplishment of the Navy's mission depends on continuous training of its personnel.

1-2. With each advancement, you MUST accept an increased responsibility in military matters only.

1-3. When talking to a group of trainees about diesel engines, why should you use precise technical and standard Navy terms?

1. To convey information accurately, simply, and clearly
2. To take advantage of the opportunity for self-improvement
3. To avoid criticism from trainees having higher formal education
4. To impress the trainees

1-4. What should you do to prevent a wide training level gap which occurs when highly skilled personnel are transferred?

1. Require strikers to devote off-duty time to increase their proficiency
2. Help those trainees who have trouble with their task
3. Emphasize training with movies, rather than on-the-job training
4. Conduct a continuous training program

● Question 1-5 is to be judged True or False.

1-5. As an EN advances, he should become more familiar with the work of other ratings so that he may direct the work of his group for maximum benefit of the organization as a whole.

1-6. Why should petty officers strive constantly to improve their grammar usage?

1. To vitalize instruction
2. To impress trainees
3. To avoid criticism
4. To exchange ideas

1-7. Why should a petty officer know the precise meanings of engineering technical terms?

1. To convey information accurately
2. To obtain information from official publications related to his work
3. To understand questions on written examinations for advancement
4. All of the above

● Question 1-8 is to be judged True or False.

1-8. If you hear anything that is new concerning the operation and maintenance of diesel engine fuel equipment, you should find out everything you can about it.

1-9. What should you do to keep abreast of new developments that affect you, your work, and the Navy?

1. Find up-to-date information and check that which pertains to your rate
2. Collect personal copies of pertinent technical manuals
3. Complete all enlisted correspondence courses that pertain to your rating
4. Complete all officer correspondence courses that are related to your rating

1-10. Which of the following statements regarding the "Quals" Manual is correct?

1. It is issued annually by the Bureau of Naval Personnel
2. It covers only the professional requirements for personnel advancement
3. It lists qualifications for general ratings but not for service ratings
4. It covers both military and professional requirements for advancement in all rates and ratings

1-11. You should provide each person in your division with detailed information on training manuals that should be studied for advancement. What publications should you consult to obtain this information?

1. Shipboard Training Manual
2. Guide for Enlisted Classification
3. Bibliography for Advancement Examination Study
4. Manual for Qualifications for Advancement

Learning Objective: Identify some of the military and occupational duties performed by EN1s and ENCs.

1-12. As an EN1 or ENC you may be required to perform which of the following assignments?

1. Maintenance and repair of machinery
2. Planning and organizing work details
3. Training and supervising lower rates
4. All of the above

1-13. The duties required of an EN1 or ENC may include which of the following actions?

1. Instructing watchstanders in the performance of their duties
2. Ensuring that safety precautions are posted in conspicuous places
3. Familiarization with equipment used by all other engineering ratings
4. All of the above

1-14. Except in cases of an emergency, the engineering officer of the watch must be authorized to turn the ship's main engines by which of the following personnel?

1. Navigator
2. Executive officer
3. Officer of the deck
4. Commanding officer

1-15. A ship is underway when a lubricating oil casualty occurs in a main reduction gear. The casualty should be promptly reported to which of the following personnel?

1. Officer of the deck
2. Engineer officer
3. Both 1 and 2 above
4. Main propulsion assistant

1-16. As specified in Navy Regulations, the duties of a ship's engineering officer of the watch include which of the following actions?

1. Ensure that the Engineering Log, Engineer's Bell Book, and prescribed operating records for the ship are properly kept
2. Make frequent inspections of the ship's engines and auxiliary equipment
3. Report to the officer of the deck and the engineer officer any actual or probable engine condition that may affect the proper operation of the ship
4. All of the above

1-17. A chief petty officer is assigned duty as the engineering department duty officer. He is responsible for which of the following actions?

1. Make all reports required by the engineering officer
2. Write the engineering log for his day's duty
3. Report the condition of the department to the CDO
4. All of the above

- Questions 1-18 is to be judged True or False.

1-18. The cleanliness of the engineering watchstanding space and the status of the firefighting equipment in that space are the responsibility of the EN1 or ENC standing the watch.

1-19. Before assuming the engineroom watch, the relieving watch should make sure that which, if any, of the following actions have taken place?

1. Bilges have been cleaned
2. All orders have been completed
3. Any uncompleted order has been received
4. None

1-20. A cold-iron watch is normally stood when a ship is in which of the following conditions?

1. Underway
2. At anchor
3. Moored to a buoy
4. Alongside a tender

Learning Objective: Identify sources of information that are helpful when studying for advancement.

1-21. To use the rate training manual Engineman 1&C to its best advantage and to gain the most from it, you should start your study by following which of the following practices?

1. Read the preface, table of contents, and index
2. Read the introduction to each chapter
3. Read chapter 1
4. Browse through the book

1-22. An EN who is preparing for the Navy-wide advancement in rate examination, should study which of the followng materials?

1. The mandatory and recommended manuals listed in the Bibliography for Advancement Examination Study, NAVEDTRA 10052
2. The knowledge factors covered in the Quals Manual
3. The mandatory manuals listed in Bibliography for Advancement Examination Study, NAVEDTRA 10052 onl
4. The publications pertinent to the professional mechanical aspects of the rating and those relating to the military requirements

1-23. How often is NAVEDTRA 10052 issued revised form?

1. Semiannually
2. Annually
3. Every 2 years
4. Every 5 years

1-24. When training junior personnel for advancement, you should stress that they are responsible for which of the following rate levels?

1. The rate level to which they seek advancement only
2. Their present and lower rate levels
3. Their present and higher rate levels
4. The rate level to which they seek advancement and all lower levels

1-25. Questions in the written advancement examinations are based on which of the following factors?

1. knowledge factors and practical factors of military and professional qualifications
2. Knowledge and practical factors of the professional qualifications only
3. Practical factors of the military and professional qualifications
4. knowledge factors of the military and professional qualifications

1-26. Which of the manuals listed in NAVEDTRA 10052 for your rating must you complete before you are eligible to take the advancement in rating examinations?

1. All manuals listed for the Engineering and Hull group
2. All manuals listed for the next higher rate
3. Only manuals listed for the next higher rate and marked with asterisks
4. Only unmarked manuals listed for the next higher rate

● Question 1-27 is to be judged True or False.

1-27. All personnel seeking advancement to PO1 or CPO must satisfactorily complete the appropriate Rate Training Manual, and the Military Requirements for Petty Officer l&C.

1-28. When you are preparing for advancement, which of the following rate training manuals will provide you with additional occupational knowledge?

1. Mathematics, Volume 1
2. Blueprint Reading and Sketching
3. Tools and Their Uses
4. All of the above

Questions 1-29 through 1-32 are to be judged True or False.

1-29. One method of judging how much you have learned from a training manual is to complete the correspondence course based on that manual.

1-30. Chapter 001 of Naval Ship's Technical Manual will be particularly important to you as an Engineman, because it gives a complete listing of all chapters included in the manual.

1-31. The Deck Plate is a magazine published monthly by NAVSEA containing information on new equipment and supplying engineering data that augments the Naval Ship's Technical Manual.

1-32. Films that may be of use as training aids are listed in the Department of the Navy Catalog of Audiovisual Production Products, OPNAVINST 3157.1.

Learning Objective: Describe some of the administrative and supervisory responsibilities of the EN1 and ENC in relation to subordinate personnel.

1-33. Which of the following areas of responsibility includes the submitting of records and reports that are associated with an engine overhaul job?

1. Administration
2. Supervision
3. Training
4. Maintenance

1-34. When machinery repairs are in progress, the supervisor is responsible for which of the following tasks?

1. Assign experienced personnel to perform the work
2. Ensure that the job is done correctly
3. Ensure that spare parts are available
4. All of the above

1-35. Which of the following statements bests describes your administrative, supervisory, and training responsibilities as an EN1 or ENC?

1. Materials, parts, tools, and trained personnel must be available when needed
2. Reports must be submitted and records must be complete and orderly
3. Individual repair jobs must be performed in a planned logical sequence
4. All of the above

1-36. As an engineman, with which of the following areas of responsibility should you be concerned?

1. Administrative, in connection with engineroom operations, maintenance and repair only
2. Supervisory, in connection with engineroom operations, maintenance and repair only
3. Administrative and supervisory, in connection with engineroom operations only
4. Administrative and supervisory, in connection with engineroom and auxiliary operations, maintenance and repair

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Learning Objective: Indicate how necessary engineering records and reports for naval ships are prescribed and obtained.

1-37. Reports for the administration and upkeep of naval ships are described by directives from which of the following authorities?

1. NAVSHIPS
2. Type commanders
3. CNO
4. All of the above

● Question 1-38 is to be judged True or False.

1-38. Information on obtaining most engineering forms and records is indicated in the Navy Stock List of Forms and Publications, NAVSUP 2002.

Learning Objective: Identify and give the purpose of legal records used in the engineering department and describe how the records should be maintained.

1-39. Which of the following engineering department records must be preserved as permanent legal records?

1. Engineering Log and Fuel and Water Report
2. Engineer's Bell Book and Mail Log
3. Engineering Log and Engineer's Bell Book
4. Machinery History and Boiler Room Room Operating Record

1-40. Which of the following statements pertaining to the Engineering Log is correct?

1. Remarks must include all minor speed changes and boilers in use
2. Spaces are provided for recording total engine miles steamed for the day, route of the ship, and the number of days out of drydock
3. An erasure is not allowed unless it is neat and the re-entry is legible
4. The Engineering Log must be prepared and signed by the senior petty officer of the watch whether he is or is not the engineering officer of the watch

1-41. Where are the instructions for making entries in the Engineering Log contained?

1. In the Naval Ship's Technical Manual
2. In the type commander's directives
3. In the U.S. Navy Regulations
4. All of the above

1-42. You are in charge of the entire underway watch when Fireman Jones slips and breaks his arm in the engineroom. Where should you record this injury?

1. In the Monthly Summary
2. In the Engineering Log
3. In the Engineer's Bell Book
4. All of the above

1-43. If an error is made in an entry to the Engineering Log, what should be done about the erroneous entry?

1. The error should be erased and the correction inserted
2. The error should be lined through once, rewritten correctly, and initialed
3. The error should be underlined and an explanatory note entered in the margin
4. The error should be circled and an explanatory note made at the bottom of the page

1-44. The commanding officer signs the Engineering Log on what day of each month?

1. The fifth calendar day
2. The tenth calendar day
3. The twentieth calendar day
4. The last calendar day

1-45. Which of the following persons is responsible for reviewing and signing the Engineering Log each day to indicate that all entries are complete and accurate?

1. Petty officer of the watch
2. CPO with the day's duty
3. Engineer officer
4. Main propulsion officer

● Question 1-46 is to be judged True or False.

1-46. Neither the petty officer of the watch, the CPO who wrote the log, nor the engineer officer may, without first obtaining permission, enter changes or additions to the Engineering Log after it has been signed by the commanding officer.

1-47. A new series of page numbers added to the Engineering Log are used starting with the first day of each

1. month
2. quarter
3. fiscal year
4. calendar year

1-48. A ship's Engineer's Bell Book provides a legal record concerning the

1. operating efficiency and general performance of the ship's engineering plant
2. time of any change in movement of the ship's propellers
3. operating efficiency of the ship's engineering plant only
4. general performance of the ship's engineering plant only

1-49. Who normally makes entries in the Engineer's Bell Book while the ship is steaming at sea?

1. The messenger
2. The throttleman
3. The CPO on duty
4. The EOOW

1-50. While a ship is entering port, entries in the Engineer's Bell Book may be made by the

1. throttleman's assistant
2. engineer officer
3. throttleman
4. engineering officer of the watch

1-51. If the bridge signals ahead 1/3 on the engine order telegraph and ahead 35 on the engine revolution telegraph, what entry should the throttleman make in (a) column 2 and (b) column 3 of the Engineer's Bell Book?

1. (a) Column 2: blank;(b) column 3: 35
2. (a) Column 2: I; (b) column 3: blank
3. (a) Column 2: I; (b) column 3: 35
4. (a) Column 2: 1/3; (b) column 3: 35

● Questions 1-52 through 1-54 are to be judged True or False.

1-52. Ships with controllable reversible pitch propellers must record in the Engineer's Bell Book any signaled speed changes by noting the shaft counter readings.

1-53. The engine miles underway are calculated from the counter readings taken each hour on the hour recorded in column 4 of the Engineer's Bell Book.

1-54. Before being relieved of the watch, the throttleman of the machinery spaces should initial the Engineer's Bell Book on the line following the last entry.

1-55. By whom and under what conditions is the Engineer's Bell Book maintained on a ship equipped with controllable reversible pitch propellers and with engines that are directly controlled either by the engineroom or from the bridge?

1. By bridge personnel at all times
2. By engineroom personnel at all times
3. By bridge personnel when engines are directly controlled from the bridge and by engineroom personnel at all other times
4. By engineroom personnel when engines are directly controlled from the bridge and by bridge personnel at all other times

1-56. Assume that a ship is equipped with controllable reversible pitch propellers and the movement of the propellers is in bridge control. Before going off watch, who signs the Engineer's Bell Book on the line following the last entry?

1. Quartermaster of the watch
2. Officer of the deck
3. Executive officer
4. Commanding officer

● Question 1-57 is to be judged True or False.

1-57. Neat corrections and erasures are permitted in the Engineer's Bell Book, if they are made only by the person required to sign the record for the watch and if the change is neatly initialed in the margin of the page.

Learning Objective: Recognize the importance of operating records and reports and indicate factors affecting the maintenance and disposal of such records.

1-58. What is the purpose of maintaining and keeping engineering operating records and reports?

1. Ensure regular inspections of operating machinery
2. Provide data for performance analysis
3. Both 1 and 2 above
4. Warn of impending casualties to operating machinery

1-59. When standard engineering operating forms are not available, who will authorize the temporary forms to be used?

1. Engineer officer
2. Executive officer
3. Squadron commander
4. Type commander

1-60. After how many years may the Diesel Engine Operating Record, All Ships (NAVSEA 9231/2), be destroyed?

1. 1 yr
2. 2 yr
3. 3 yr
4. 4 yr

1-61. Which of the following persons approves the diesel engine operating logs?

1. Petty Officer of the Watch
2. Engineer officer
3. Senior engineman
4. Watch supervisor

1-62. Why is a daily Fuel and Water Account maintained by the engineering department?

1. Because it may be used to form the basis of other reports
2. Because it is used to inform selected personnel of the liquid load
3. Both 1 and 2 above
4. Because it must be submitted to the type commander

1-63. If you were assigned to compute the amount of burnable fuel aboard ship, you would compute

1. all the fuel in the service, storage, and settling tanks
2. all the fuel in the service and storage tanks only
3. only the fuel above the service and storage tank suction line
4. only the fuel above the service tank suction line

● Question 1-64 is to be judge True or False.

1-64. The original copy of the Fuel and Water Report is submitted to the commanding officer daily with the 1200 reports.

● Questions 1-65 through 1-68 concern the Monthly Summary of Fuel Inventory and Steaming Hours Report (short title: Monthly Summary).

1-65. After the Monthly Summary has been been prepared, who must verify the amount of fuel received for the month?

1. The commanding officer
2. The supply officer
3. The type commander
4. The engineer officer

1-66. Which of the following is a true statement about a ship's Monthly Summary for a given month?

1. The commanding officer signs the copy which goes to the type commander
2. The engineer officer signs the copy which goes to the files of the engineering department
3. The original is forwarded to the fleet commander by the fifth of the next month
4. The hours-not-underway entries are made on the back of the report

1-67. Where may you find additional information regarding the use of definitions and explanations in the preparation of the Monthly Summary?

1. OPNAVINST 5213.7
2. NWIP 10-1 (revised)
3. Fleet Commander's Instructions
4. OPNAVINST 3540.1

● Question 1-68 is to be judged True or False.

1-68. Many engineer officers facilitate the preparation of the Monthly Summary by recording operating information on a daily basis.

1-69. Information about engineering records that must be kept permanently is contained in

1. Naval Ship's Technical Manual
2. SECNAVINST P5212.5
3. NAVSHIPS 5083
4. NAVSHIPS 3648

1-70. The Engineering Log must be retained aboard ship for a period of how many years?

1. 1 yr
2. 2 yr
3. 3 yr
4. 4 yr

1-71. What disposition is made of a ship's Engineer's Bell Book if the ship is scrapped?

1. It is scrapped
2. It is sent to the nearest Naval Records Management Center
3. It is sent to NAVSHIPS
4. It is sent to BUDOCKS

1-72. A NAVSEA report that has served its purpose and is no longer useful may be destroyed after how many months?

1. 1 month
2. 12 months
3. 3 months
4. 24 months

Assignment 2

Administration, Supervision, and Training (cont)

Textbook Assignment: Engineman 1&C, NAVEDTRA 10543-E1, Pages 2-12 through 2-39

Learning Objective: Recognize the purpose and the importance of Trend and Spectrographic Analyses.

- Question 2-1 is to be judged True or False.

2-1. Trend and spectrographic analyses are used to spot impending engine malfunctions.

2-2. Which of the following is a means used to determine if an engine needs to be overhauled?

1. The current operating data is compared with the previous operating data
2. The operating data of the engine is compared with that of another engine of the same type
3. The temperature of the lube oil entering the oil cooler is compared to that of the one leaving the cooler
4. The last two operating data sheets are compared

2-3. How are engine performance data used as a tool?

1. They are used to circle the readings that are out of limits
2. They are used to make graphs
3. They are used to bring the out of limit readings to the attention of the engineer officer
4. They are used to discuss the operating data with all operators

2-4. In order to produce meaningful graphs for a generator, what load percentage should the data indicate?

1. 25%
2. 50%
3. 80%
4. 100%

- Questions 2-5 and 2-6 are to be judged True or False.

2-5. In most cases, a set of readings should be plotted every 200 hours of engine operation.

2-6. Engine performance data should be obtained within 5 minutes after start up.

2-7. When preparing a graph, at what operating hour do you place your first point for lube oil consumption?

1. 100
2. 200
3. 300
4. 400

2-8. Which of the following information can be obtained from the curves on graphs?

1. The condition of the engine
2. What needs to be done to the engine
3. The life expectancy of vital parts
4. All of the above.

2-9. What can you determine from a spectrometric analysis of engine oil?

1. The extent of accelerated wear of an internal combustion engine
2. The amount of oil the engine uses per month
3. The rate of flow of the cooling water to the lube oil cooler
4. The amount of oil pressure produced by the lube oil pump

- Questions 2-10 and 2-11 are to be judged True or False.

2-10. After major overhaul, ships should, maintain accurate records of operating hours, including oil changes, and samplings in order to provide the testing facility with the information indicated in the sampling kit.

2-11. After an oil sample is received at a shipyard or an IMA, a physical test and a spectrometric analysis are performed.

Learning Objective: Point out some administrative and supervisory responsibilities in relation to subordinate personnel, the procurement of repair parts and materials, scheduling jobs, and estimating time and materials for a job.

2-12. In addition to the supply officer, who is responsible for taking the initiative in maintaining an adequate supply of engineering spare parts?

1. Engineer officer
2. Main propulsion assistant
3. Prime users of the parts
4. Senior supply petty officer

2-13. Aboard ship, which of the following is NOT one of your responsibilities in connection with maintenance and repair?

1. To select materials on the basis of service conditions they must withstand
2. Issue and account for material required for the support of the ship
3. Identify repair parts from machinery that is familiar to you
4. Know where to look for information on repair parts and material you will use

2-14. What should you do when materials and repair parts are not specified in the instructions accompanying a job?

1. Always use your own judgment
2. Never use your own judgment
3. Look for the information
4. Refuse the job until you are provided with the information

2-15. Which of the following sources of information is helpful in identifying or selecting materials and repair parts?

1. Stock cards maintained by the supply officer
2. Ship's plans and blueprints
3. Coordinated Shipboard Allowance List
4. All of the above

2-16. Which of the following sources of information should you consult to obtain the National Stock Numbers of repair parts for a diesel engine cylinder liner and gaskets?

1. Planned Maintenance System Manual
2. Coordinated Shipboard Allowance List
3. Nameplate on the equipment
4. Each of the above

2-17. What document should you use to request a repair item stocked in the supply department aboard ship?

1. DD Form 1150
2. DD Form 1348
3. NAVSUP Form 1250
4. NAVSUP Form 4757

2-18. Which of the following sources of information is/are NOT likely to identify the type of material used in manufacturing a gear for a fuel oil service pump?

1. Nameplate on the pump
2. Stock cards maintained by the supply officer
3. Ship's plans and blueprints
4. Coordinated Shipboard Allowance List

● Questions 2-19 and 2-20 are to be judge True or False.

2-19. When unable to locate the National Stock Number of an item you are requesting from a shipboard supply department, you should furnish the supply personnel with enough standard information to help identify the item.

2-20. SECAS is the designated system responsible for maintaining the CASREP status of your ship.

2-21. Who is responsible for ensuring that the proper documentation is completed and processed as described in Volume II of OPNAVINST 4790.41

1. The commanding officer
2. The engineer officer
3. The work center supervisor
4. The ship's 3-M coordinator

2-22. At the individual equipment level, which of the following forms is used to report a configuration change?

1. OPNAV Form 1250
2. OPNAV Form 1348
3. OPNAV Form 4790/2K
4. OPNAV Form 4790/CK

2-23. A work request to repair a pump shaft has been designated as a ship-to-ship job. Which of the following actions will the ship's force personnel be expected to perform?

1. Disassemble the pump and remove the shaft
2. Deliver the shaft to the repair shop
3. Pick up the shaft when the repair work has been completed
4. All of the above

2-24. All tests required to be performed by Quality Assurance must be witnessed by the

1. commanding officer
2. ship's force
3. type commander
4. SIMA repair officer

2-25. Under which of the following conditions would you use the OPNAV Form 4790/2K?

1. To request transferring a piece of equipment to another work center
2. To request PMS Maintenance Requirement Cards
3. To request a shipyard's assistance
4. To request consumable materials

2-26. What is the purpose of the OPNAV Form 4790/2L?

1. To defer a piece of equipment
2. To document completion of a job order
3. To request work from an IMA
4. To amplify information described on a 4790/2K

2-27. Which of the following forms is an automated work request produced by an IMA with computer capabilities?

1. OPNAV Form 4790/2K
2. OPNAV Form 4790/2L
3. OPNAV Form 4790/2Q
4. OPNAV Form 1348

2-28. Checking on the availability of materials before starting work on a maintenance job is an important part of careful planning because failure to do so may result in which of the following conditions?

1. Wasted effort
2. Unsafe working condition
3. Useless equipment
4. All of the above

2-29. The amount of information required to be given to the personnel doing a particular repair job will depend largely on which of the following considerations?

1. The safety precautions you expect them to ignore
2. The manhours estimated to complete the job
3. The experience of the personnel assigned to the job
4. The degree of care with which you expect to inspect the job upon completion

● Question 2-30 is to be judged True or False.

2-30. A careful inspection should be conducted after a job has been completed to ensure that the work was properly performed and that necessary records or reports have been prepared.

2-31. When estimating the amount of time required to accomplish a repair, what factor(s) should you take into consideration?

1. The personnel who can best do the job
2. The number of personnel required for the work
3. The availability of the repair materials
4. Each of the above

● Questions 2-32 and 2-33 are to be judged True or False.

2-32. The accuracy of job estimates that you must submit to your division officer is important because such estimates may affect the operational schedule of the ship.

2-33. When more than one shop is required to complete an engine repair, each shop should make a separate time estimate of the job.

2-34. Besides the actual time required for the work itself, what other factors must be considered in arriving at a final estimate for a particular job?

1. Drills
2. Inspections
3. Working parties
4. All of the above

● Question 2-35 is to be judged True or False.

2-35. Dividing a total job into sub-jobs and then determining the time and number of personnel required for each sub-job is a waste of labor and time for the purpose of arriving at accurate estimates.

2-36. Which of the following estimates is often the most difficult for a supervisor to make in arriving at a job completion time?

1. Tools required
2. Materials required
3. Personnel required
4. Time and labor required

2-37. You are responsible for submitting an estimate of the materials required to complete a job. If the job is one your shop handles regularly, which factor is a basis for making an accurate estimate?

1. Records of the jobs kept by the shop
2. In-service conditions to be fulfilled
3. Condition of tools and equipment
4. Availability of the materials

● Question 2-38 is to be judged True or False.

2-38. In estimating material needs for a job, you should make allowances for waste.

Learning Objective: Indicate practices and procedures used when training personnel.

2-39. In addition to the technical competence that you must possess before you can teach others, which of the following functions should you also be capable to perform?

1. Organize information
2. Present information effectively
3. Motivate your students
4. All of the above

● Question 2-40 is to be judged True or False.

2-40. From a training standpoint, each person on watch in the engineroom is required to function as part of a team because of the close relationship between each watchstander's duties.

2-41. Which of the following factors helps determine the procedures for training a new person in engineroom operations?

1. Ship's operating schedule
2. Number of experienced men available
3. Condition of engineroom machinery
4. Each of the above

2-42. An Engineman striker who is newly assigned to the engineroom is not ready for messenger duty training until he becomes familiar with the

1. duties of the throttleman
2. technique of reading pressure gages
3. procedures of starting or securing the main propulsion plant
4. locations of all machinery, equipment, piping, and valves

2-43. During what part of an engineroom watchstander's training should a student learn how to take gage readings?

1. While learning the duties of the throttleman
2. While learning the duties of the messenger
3. After becoming proficient in the duties of the throttleman
4. After learning to perform the duties of the throttleman

2-44. When should an Engineman striker be trained to perform the duties of a throttleman?

1. After becoming competent in administrative requirements
2. After becoming proficient in the duties of the messenger
3. While learning the duties of the messenger
4. While learning specific basic safety precautions

● Questions 2-45 and 2-46 are to be judged True or False.

2-45. A good way to start on-the-job training for the throttleman's job is to assign an experienced throttleman to supervise the trainee.

2-46. As the instructor of engineroom personnel, you should analyze and apply your own experiences and reactions to help trainees learn more effectively.

2-47. Which of the following factors should be included in the training of engineroom personnel?

1. Consideration of the individual difference in the learning rates of personnel
2. Time to be spent on engine theory prior to manual operation
3. Encouragement of personnel to notice and discuss differences in the ways that engines behave during operation
4. Each of the above

● Question 2-48 is to be judged True or False.

2-48. An experienced Engineman reporting aboard for duty from another type of ship will require a certain amount of retraining to qualify as a watchstander.

2-49. Which of the following factors should be emphasized constantly throughout an engineroom training program?

1. Safety precautions
2. Trial-and-error techniques
3. Emergency repair procedures
4. Machinery characteristics

● Questions 2-50 through 2-53 are to be judged True or False.

2-50. The PQS program is a method designed to ensure quality assurance.

2-51. Most PQS standards are divided into four sections.

2-52. The watchstation section defines the actual duties, assignments, and responsibilities needed for qualification.

2-53. As a work center supervisor, it is NOT absolutely necessary for you to be PQS qualified in all the equipment under your control.

2-54. When personnel are assigned to repair V, where should the emphasis be placed?

1. PQS, qualification in damage control
2. PQS, qualification in engineroom takeover
3. PQS, qualification in ship's 3-M system
4. PQS, qualification in first aid

2-55. As a repair party leader, you are responsible for which of the following functions?

1. Knowing how many personnel on the ship are fully qualified in damage control
2. Training your repair party personnel on the equipment they will be using
3. Training your repair party personnel in the function of a repair party
4. Both 2 and 3 above

2-56. What two Status Boards is Repair V required to maintain?

1. Stability and liquid load
2. Auxiliary and main propulsion machinery
3. Air and surface contacts
4. Personnel casualty and radiological

Learning Objective: Recognize the purpose and the importance of the Engineering Operational Sequencing System (EOSS).

● Question 2-57 is to be judged True or False.

2-57. The EOSS was developed to help combat the problems created by rapid turnover of personnel and the lack of needed information.

2-58. When the EOSS is used properly it accomplishes which of the following considerations?

1. Reduces operational casualties
2. Provides better plant control
3. Extends the operational life of machinery
4. All of the above

2-59. Under Stage I of the EOP, who has direct control of an evolution involving the starting and securing of a main engine?

1. The engineering officer of the watch
2. The engineroom top watch
3. The main propulsion asistant
4. The engineer officer

2-60. How does the EOP documentation help the EOOW?

1. It helps him to select equipment combinations for plant efficiency
2. It helps him to train newly assigned personnel
3. It helps him to properly schedule operational events
4. It helps him to perform all of the above tasks

2-61. To help assist the plant supervision with an operation involving the shifting of the ship's service generator, the EOP section of the EOSS provides him with which of the following documents?

1. Plant procedure charts
2. A diagram for plant steaming conditions
3. Plant status boards
4. All of the above

● Question 2-62 is to be judged True or False.

2-62. Stage II of the EOP can be used by the space supervisor to assist in the training of newly assigned personnel in the operation of equipment.

2-63. All engineroom watchstanders can increase their ability to control and prevent casualties by studying which of the following publications?

1. The user's guide
2. The EOCC manual
3. The EOP manual Stage I
4. The EOP manual Stage II

2-64. Which of the following elements must be included in a well administered and effective casualty control training program?

1. Recognition of the symptoms
2. Probable causes and effects
3. Preventive action necessary to reduce, eliminate, or control casualties
4. Each of the above

Assignment 3

Administration, Supervision, and Training (Cont'd)

Textbook Assignment: Engineman 1&C, NAVEDTRA 10543-E1, Pages 2-39 through 2-53

Learning Objective: Recognize the purpose of and the types of inspections held in the engineering department aboard ship, and describe the methods and procedures for conducting each.

● Information for questions 3-1 and 3-2. An inspection party from destroyer A boards destroyer B and proceeds to carry out a competitive material inspection.

3-1. Which of the following officers most probably determined the type of inspection to be held aboard destroyer B?

1. Fleet commander
2. Type commander
3. Commanding officer of destroyer B only
4. Commanding officer of destroyer B and the commanding officer of destroyer A

3-2. The inspection party was most probably selected by the

1. CNO
2. type commander
3. division commander
4. commanding officer of destroyer A

● Questions 3-3 and 3-4 are to be judged True or False.

3-3. The administrative inspection of a ship's engineering department is concerned with the ship's readiness to carry out its basic mission.

3-4. The appearance of the engineering personnel is evaluated for grading purposes during administrative inspections.

3-5. During the general administration inspection, which of the following has a direct bearing on the ship's engineering department?

1. Acquaintance of engineering personnel with the ship's administrative procedures
2. Proper maintenance of operating logs
3. Indoctrination procedures for new personnel
4. All of the above

3-6. An administrative inspection of a ship's engineering department is principally concerned with the department's

1. paper work
2. administration of divisional responsibilities
3. assignment of personnel to administrative duties
4. training facilities

3-7. Who normally provides checkoff lists for administrative inspections of ships?

1. Type commander
2. Division commander
3. Captain of the ship that will conduct the inspection
4. Captain of the ship that will be inspected

3-8. An administrative inspection is being conducted in the engineering department. Which of the following bills should be inspected by the assistant inspector for adequacy, completeness, and correctness?

1. Fueling Bill
2. Engineering Casualty Bill
3. Watch, Quarter, and Station Bills
4. All of the above

3-9. The best way for an inspector to determine whether personnel are familiar with the operating instructions of their department is to question the

1. department head concerning the methods of instruction
2. leading petty officers of the department
3. newly assigned or nonrated personnel in the department
4. personnel at random

3-10. How does an inspector determine the methods employed in the engineering department to locate stowed items?

1. By examining the various supply records and forms
2. By inspecting the stowage bins and boxes
3. By asking a senior petty officer how he would locate an item
4. By questioning a department officer on the methods employed

3-11. What type of inspection is mainly concerned with a ship's ability to carry out its wartime missions?

1. Administrative inspection of the ship as a whole
2. Administrative inspection of the ship's departments
3. Operational readiness inspection
4. Material inspection

3-12. Which of the following types of inspections include battle problems?

1. Material inspections and operational readiness inspections
2. Operational readiness inspections only
3. Material inspections only
4. All formal inspections

3-13. HOW is a ship's performance during its operational readiness inspection measured?

1. By the standard of professional ability attained by the crew
2. By the ship's ability to perform its wartime functions adequately
3. By the completeness, adequacy, and implementation of its Battle Bill
4. All of the above

3-14. The operational readiness observing party differs from the administrative inspecting party in that it usually contains

1. fewer warrant officers
2. more third class petty officers
3. fewer commissioned officers
4. more leading petty officers

3-15. What is the primary function of the battle problem as it is related to the engineering department of a ship?

1. To test the teamwork within the department
2. To evaluate the quality of the ship's equipage
3. To test the skill of rated personnel in the department
4. To measure the operational efficiency of the engineering machinery

3-16. The value of a battle problem to a ship's company is directly proportional to the

1. amount of preparation time allowed the ship's company before zero problem time
2. amount of realism provided in the problem
3. skill of the observing party evaluating operational procedures
4. number of trained observers conducting the problem

3-17. What specific element increases the value of a battle problem to a ship's company?

1. Surprise
2. Dress rehearsal
3. Advance notice
4. Suspense

3-18. Which of the following types of information should be supplied to a ship before a battle problem begins?

1. The time of "darken ship" inspection
2. The time of a simulated casualty to the power supply
3. The end of problem time
4. The time of JV telephone circuit casualty

● Question 3-19 is to be judged True or False.

3-19. When practicable, during a battle problem, pertinent information should be given verbally by observers to the ship's crew.

3-20. When may an observer coach ship's personnel during a battle problem?

1. When questioned by personnel concerning imposed casualties
2. When imposed casualties are undiscovered by personnel
3. When it is inconvenient to simulate casualties
4. When the corrective action taken by personnel is inappropriate

3-21. During a battle problem, a valve must be closed in order to simulate a casualty to a main engine. Which of the following personnel should actually close the valve?

1. The assistant inspector
2. A member of the observing party
3. A member of the ship's engineering force
4. Either a member of the ship's engineering force or a member of the observing party

3-22. During a battle problem, an observer has requested that the feedwater to the boilers be shut off to simulate a boiler casualty. What should the engineer officer of the watch do?

1. Direct the engineroom personnel to do whatever the observer requests
2. Not permit this to be done
3. Make sure the supply of lubricating oil to the main engines is stopped at the same time
4. Allow only the observer to handle the shutoff valve

3-23. Which of the following personnel are responsible for setting up provisions for emergency action in case of a real casualty during a battle problem?

1. Type commander
2. Ship's company and the observing party
3. Ship's company only
4. Observing party only

3-24. Who uses the engineering telephone circuits during the battle problem?

1. The observing party, to announce start and end of the problem
2. The observing party, in case of actual casualty
3. The ship's personnel, in case of actual casualty
4. The ship's engineering personnel, to cope with the battle problem assigned to the ship

● Question 3-25 is to be judged True or False.

3-25. In a shipboard battle problem, observers should use equal effort to note excellence as well as weakness.

3-26. The analysis of a battle problem is divided into two steps:

1. critique and observers' reports
2. captain's report and observers' reports
3. critique and ship's company report
4. observers' and ship's company reports

3-27. Which of the following personnel attend the critique that is held aboard ship after a battle problem?

1. Commanding officer, department heads, chief observer, and senior observers
2. All ship's officers, chief observer, and senior observers
3. All ship's officers, some chiefs and first class petty officers, chief observer, and senior observers
4. All ship's officers, some chiefs and first class petty officers, and chief observer

3-28. Who sets down the format of the observers' reports?

1. The senior observer for each department
2. The chief observer
3. The type commander
4. The fleet commander

3-29. After an operational readiness inspection, one purpose of supplying the inspected ship with copies of the inspector's report is to provide the inspected ship with a

1. checkoff list for correcting defects
2. statement of probable action by the type commander
3. schedule for future overhaul periods
4. statement of condition of material in comparison with other ships in the division

3-30. When evaluating the performance of an engineering department during a battle problem, an observer checks the extent to which the engineering department carries out which of the following tasks?

1. Exercises engineering casualty control measures
2. Utilizes damage control features built into the ship
3. Maintains maximum mobility and manueverability of the ship
4. All of the above

3-31. The specific purpose of the material inspection is to determine whether the

1. ship's machinery is kept clean
2. cleanliness of a ship's compartments meets acceptable standards
3. correct procedures are being used in the maintenance of machinery and equipment
4. military bearing and appearance of a ship's personnel have improved materially since the last inspection

3-32. Which of the following types of inspections is similar to the Board of Inspection and Survey inspection?

1. The shipwide administrative inspection
2. The departmental administrative inspection
3. The material inspection
4. The operational readiness inspection

● Question 3-33 is to be judged True or False.

3-33. Unless they have a direct bearing on the material condition, administrative methods and cleanliness should NOT be considered as part of a material inspection.

3-34. A list of the units to be opened is furnished to the ship for material inspection by the

1. type commander
2. Board of Inspection and Survey
3. chief inspector
4. individual inspectors

● Question 3-35 is to be judged True or False.

3-35. All material deficiencies found during an inspection, but NOT included on the Work List are noted as discrepancies by the chief inspector.

3-36. The information on the condition sheets provided to the inspection party describes the condition of

1. the machinery to be opened
2. the machinery to be tested
3. all parts of the ship, and all machinery and equipment on board
4. machinery to be operated

3-37. The preliminary copies of the condition sheets to be used for a material inspection are filled in by the

1. type commander
2. division commander
3. ship that conducts the inspection
4. ship to be inspected

3-38. Which of the following items should be entered on a condition sheet?

1. Machinery to be opened for inspection
2. Equipment to be operated
3. Material condition of an inoperative safety device
4. All of the above

● Question 3-39 is to be judged True or False.

3-39. Condition sheets describe the condition of the ship's hull, machinery, and equipment. Condition sheets are filled in by the inspected ship's company and used by the inspection party as a checkoff list and inspection record during the inspection. After the inspection, condition sheets are used in preparing the final inspection report on the condition of the ship.

3-40. Why is chapter 090 of the Naval Ships' Technical Manual important?

1. It is a guide for use when opening particular machinery units
2. It is a comprehensive material inspection guide
3. It is a guide for preparing Work Lists
4. It is a guide for preparing Condition Sheets

3-41. Who furnishes the condition Sheets used in material inspections?

1. Inspecting party
2. Inspected ship
3. Division commander
4. Type commander

3-42. Which of the following statements describes the manner in which a material inspection should proceed?

1. All equipment of the same type should be inspected simultaneously
2. A predetermined inspection schedule should be followed
3. Inspection of each space should be completed before the next is begun
4. Inspections of all units should be made with the knowledge and assistance of ship's personnel

3-43. Which of the following is a main inspection item for a material inspection of engineering spaces?

1. Procedures used for the replacement of repair parts
2. Installation and maintenance of required firefighting equipment in the engineering spaces in accordance with up-to-date procedures
3. Maintenance of equipment custody cards
4. Knowledge by responsible engineering personnel of current instructions regarding routine testing and inspections

3-44. After a material inspection, one purpose of supplying the inspected ship with copies of the inspector's report is to provide the ship with a

1. checkoff list for correcting defects
2. statement of probable action by the type commander
3. schedule for future overhaul periods
4. statements of condition of material in comparison with other ships in the division

3-45. Who evaluates the results of a material inspection on the basis of reports submitted to the inspector of each inspection group?

1. CNO
2. Type commander
3. Ship's commanding officer
4. Chief inspector

3-46. The main difference between a material inspection group and the Board of Inspection and Survey is that the Board

1. is interested mainly in operational readiness
2. is not from Forces Afloat, but is especially appointed
3. contains at least 10 officers
4. is interested mainly in administrative efficiency

3-47. Following a shipboard material inspection, which of the following items will be included in the report submitted by the Board of Inspection and survey?

1. The general condition of the ship
2. The suitability of the ship for further service
3. A list of proposed repairs, alterations, and design changes
4. All of the above

3-48. After conducting trials and inspections of a new or converted ship prior to final acceptance for naval service, the Board of Inspection and Survey will include in its report all of the following information EXCEPT the

1. recommended changes in design
2. existing defects and deficiencies in material and performance
3. explanation of how speed and shaft horsepower are determined
4. opinion as to who is responsible for correcting reported defects

3-49. To whom does the Board of Inspection and Survey submit recommendations for the acceptance or rejection of a new ship?

1. Bureau of Ships
2. Prospective fleet commander
3. Chief of Naval Operations
4. Secretary of the Navy

3-50. Which of the following tests are included in the acceptance trial tests?

1. Full power runs and boiler overload tests
2. Quick-reversal and backing tests
3. Steering and anchor engine tests
4. All of the above

Learning Objective Indicate familiarity with and the procedure for conducting routine ship's trials.

3-51. Which of the following trials are considered routine ship's trials?

1. Laying up, final acceptance, and recommissioning
2. Tactical, standardization, and post repair
3. Economy, post repair, and full power
4. Preliminary acceptance, economy, and builder's

3-52. Which of the following ships should be required to have a post repair trial?

1. An MSO deploying to the Mediterranean
2. A DE finishing extensive repairs to its hull
3. An AO switching home ports from Norfolk to San Diego
4. A CVS completing a routine naval shipyard overhaul period

3-53. Who determines the specific nature of a post repair trial?

1. Type commander
2. Commanding officer of the ship
3. Shipyard commander
4. Both 2 and 3 above

3-54. Before a competitive trial is conducted, how much time is a ship normally allowed to test and adjust the machinery overhauled by naval shipyard personnel?

1. 1 week
2. 2 weeks
3. 20 days
4. 1 month

3-55. Which of the following ship's trials is a competitive trial?

1. Standardization
2. Economy
3. Tactical
4. Recommissioning

3-56. Before a full power trial, the ship's engineer officer makes a report on the condition of the engineering plant to the

1. Board of Inspection and Survey
2. chief inspector
3. engineering inspector
4. commanding officer

3-57. What kind of trouble can be expected when a full power trial is held in shallow water?

1. Excessive speed
2. Multiple pump failures
3. Overloading of the propulsion plant
4. Foaming of lube oil in reduction gears

3-58. A full power trial planned for 3 hours duration has to be interrupted at the end of 2 hours. What action should be taken?

1. The remaining hour of the full power trial should be completed at the first opportunity
2. Two more hours of full power trial should be conducted at the first opportunity
3. The trial should be regarded as unsatisfactory and another trial of 3 hours duration should be held at the first opportunity
4. The trial should be regarded as unsatisfactory and a special report should be made to the Board of Inspection and Survey

3-59. When should the displacement corresponding to the ship's draft be recorded during a trial run?

1. At the start and end of the trial only
2. At the middle of the trial only
3. At the start, middle, and end of the trial
4. Every hour of the trial

3-60. Who determines the full-power rpm requirements for a ship that is running a full-power trial?

1. The chief observer
2. The type commander
3. BUSHIPS
4. The Chief of Naval Operations

● Question 3-61 is to be judged True or False.

3-61. Before the official full power trial period starts, the ship is normally operated at full power long enough to permit all readings to become constant.

3-62. An economy trial is normally conducted over a period of

1. 6 hr
2. 5 hr
3. 3 hr
4. 4 hr

● Question 3-63 is to be judged True or False.

3-63. When a ship fails a performance trial, the type commander may specify a retrial which he deems appropriate to, demonstrate satisfactory engineering readiness.

3-64. Which of the following actions is NOT a duty of the assistant chief observer?

1. Taking counter readings
2. Supervising the engineroom observers
3. Checking tank soundings
4. Checking fuel oil meter readings

3-65. Which of the following personnel makes out the economy trial report?

1. Commanding officer
2. Chief observer
3. Assistant chief observer
4. The assistant observers

3-66. What information should be furnished in writing to the chief observer prior to the start of a full power trial?

1. Date of last undocking
2. Dates of last testing of all machinery safety devices
3. Authorized and actual settings of all main machinery safety settings
4. All of the above

3-67. When a minimum draft has NOT been specified by trial requirements, the liquid loading should NOT be less than what percentage of the full load capacity?

1. 25%
2. 50%
3. 75%
4. 90%

3-68. When should the chief observer determine the ship's draft and trim for a trial?

1. Before and after the trial
2. At the middle of the trial
3. At the start, middle, and end of the trial
4. Every hour of the trial

3-69. A competitive trial report normally includes data on

1. condenser water injection and discharge temperatures
2. consumption of fuel oil per hour
3. bearing clearances before and after the trial
4. ship's trim under full power

3-70. How often are readings taken and recorded during an economy trial?

1. Every half hour
2. Every hour
3. At the start and end of the trial
4. At the start, middle, and end of the trial

3-71. A ship undergoing a 4-hour full power trail is equipped with a torsionmeter for measuring shaft horsepower. To determine the power being developed, how many observations should be taken?

1. At least one during the trial
2. At least two during the trial
3. At least one each hour
4. At least two each hour

3-72. Which of the following is NOT a responsibility of engineering department personnel during an engineering trial?

1. To provide observers with a written statement of the date of the ship's last undocking
2. To ensure that clocks are synchronized in all engineering spaces and on the bridge
3. To provide the usual "housekeeping" and auxiliary loads
4. To check the setting of machinery safety devices

Assignment 4

ENGINE MAINTENANCE

Textbook Assignment: Engineman 1&C, NAVEDTRA 10543-E1, Pages 3-1 through 3-24

Learning Objective: Describe the procedure and equipments used to inspect and test-run diesel engines.

- Questions 4-1 through 4-4 are to be judged True or False.

4-1. A comparatively minor engine malfunction, if not recognized and remedied in its early stages,never develops into a major casualty.

4-2. Work center personnel must learn to recognize symptoms of developing malfunctions by using the senses of sight, hearing, smell, and touch.

4-3. Because of the safety features which are commonly incorporated in pumps and similar equipment, considerable loss of capacity may occur before any external evidence of damage is apparent.

4-4. When a material failure occurs in any unit, a prompt inspection of all similar units will NOT prevent a wave of similar casualties.

4-5. A spring-balanced indicator uses which of the following types of pistons?

1. Trunk
2. Inverted
3. Ball
4. Check

- Questions 4-6 and 4-7 are to be judged True or False.

4-6. The Kiene indicator is used only to measure the firing pressure of an engine.

4-7. A multivolt meter is used to measure the voltage produced by the thermocouples installed in an engine's exhaust system.

Learning Objective:Specify what maintenance and adjustments are required on temperature regulators, and recognize some of the troubles that may be encountered.

- Question 4-8 is to be judged True or False.

4-8. For maximum temperature control, the bulb of the temperature regulator should always be installed in the inlet side of the engine cooling water piping system.

4-9. At which of the following points should the valve stem of a temperature regulator be lubricated?

1. Where the valve stem enters the stuffing box
2. Around the threaded sleeve used for manual control
3. Both 1 and 2 above
4. At the temperature adjusting wheel

4-10. What should you do if the temperature of the freshwater leaving the engine becomes too high when the regulator is set on the lowest adjustment setting?

1. Make sure that the manual pointer is set at the THERMOSTATIC position
2. Make sure that the packing gland is not binding the valve stem and the valve stem is not stuck in the minimum cooling position
3. Make sure that the temperature control element is operating properly
4. All of the above

4-11. The temperature at the bulb of the temperature regulator drops below the set temperature and the valve position indicator shows COOLER CLOSED. Which of the following remedial measures should you take?

1. Secure the packing gland nut wrench tight
2. Grind the valve seats until a perfect seal is achieved
3. Insert the bulb into the ship's piping in the horizontal position with the arrow on the indicator disk point downward
4. Insert the bulb into the ship's piping in the vertical position with the nut at the top of the unit

4-12. Why should a liquid filled bulb of a temperature regulator be installed either in the vertical position with the nut up or in the horizontal position with the arrow up?

1. To allow the liquid level to be above the end of the internal capillary tube
2. To allow the liquid level to be below the capillary tube
3. To prevent liquid from effecting the bellows
4. To ensure that the arrow on the indicator disk is always pointing upward

● When answering questions 4-13 through 4-15, assume you are in the process of adjusting a temperature regulator to the diesel engine freshwater cooling system.

4-13. The manual crankpin should be rotated until the pointer is aligned with which of the following marked positions on the indicator plate?

1. Cooler closed
2. Cooler bypass
3. Thermostatic
4. Each of the above

4-14. When is the indicator slid up or down for adjustment to the proper position?

1. After the lower end of the seating sleeve comes in contact with the lower end of the thermostatic stem
2. Before the lower end of the seating sleeve comes in contact with the lower end of the thermostatic stem
3. After the lower end of the seating sleeve comes in contact with the upper end of the thermostatic stem
4. Before the upper end of the seating sleeve comes in contact with the lower end of the valve stem

4-15. The indicator plate is secured and the pointer and thermostatic center marks are aligned. What is the final valve stem adjustment you should make prior to tightening the locknut?

1. Two complete turns into the thermostatic stem past the seating sleeve contact
2. One complete turn into the thermostatic stem past the seating sleeve contact
3. Two complete turns into the thermostatic stem past the poppet valve seating position
4. One complete turn into the thermostatic stem past the poppet valve seating position

4-16. If the desired temperature of the water in a diesel engine cooling system is 160°F, a properly adjusted temperature regulator will maintain the water at a temperature between

1. 150° and 160°F
2. 150° and 170°F
3. 160° and 170°F
4. 160° and 180°F

Learning Objective: Recognize the purpose and types of heat exchangers; indicate what factors affect their operation; and point out the methods of maintenance and repair.

4-17. In a marine cooling system installation, which of the following engine coolants may be circulated through a heat exchanger?

1. Oil
2. Freshwater
3. Saltwater
4. Both 2 and 3 above

● Question 4-18 is to be judged True or False.

4-18. The two basic types of heat exchangers used on engines are radiator and tubular.

4-19. In the Harrison-type heat exchanger, how do the liquid coolants pass through the unit?

1. Freshwater passes through the tubes, and seawater passes around the tubes
2. Freshwater passes through the tubes, and freshwater passes through the tubes
3. Seawater passes through the tubes, and freshwater passes around the tubes
4. Seawater passes through the tubes, and the seawater passes around tubes

4-20. How is excessive scale on the cooler of a heat exchanger usually indicated?

1. By a slow increase in freshwater temperature
2. By a similiarity between inlet and outlet pressures
3. By the decrease in freshwater temperature
4. By a rise in the freshwater tank level

4-21. The temperature in the saltwater cooling system of an engine should never be allowed to exceed what maximum temperature?

1. 130°F
2. 140°F
3. 170°F
4. 180°F

4-22. Which of the following conditions can cause a cooler element to become clogged with foreign matter?

1. Leak in oil cooler
2. Dirty freshwater
3. Faulty seawater strainers
4. All of the above

● Questions 4-23 is to be judged True or False.

4-23. Overlubrication of the circulating water pump bearings will NOT affect the cooling capacity to the heat exchanger element.

4-24. Erosion holes in the cooler element of a heat exchanger are usually caused by which of the following conditions?

1. A clogged cooler element
2. A low-pressure water flow
3. Air entrapped in the cooler casing
4. Fast movement of grit particles

4-25. By which of the following actions will you cause internal leaks of a heat exchanger element installed in the engine cooling system?

1. By increasing the oil temperature of the cooler
2. By reducing the water pressure to the cooler
3. By allowing continued cooler operation at excessive pressure
4. By allowing continued cooler operation at reduced pressure

4-26. The heat exchanger outlet side is used to admit the proper amount of steam required to blow through a clogged cooler element containing which of the following deposits?

1. Oil
2. Sand
3. Grease
4. Roth 2 and 3 above

4-27. YOU are performing an air test on a heat exchanger to check for leaks. What should you do after attaching a pressure gage to the inlet line of the element?

1. Immerse the element in a tank of water
2. Block off the discharge side of the element
3. Admit low-pressure air to the inlet side of the element
4. Remove the element from the casing

4-28. Which of the following methods should you use to make an emergency repair to a strut-type heat exchanger?

1. Plug the tube
2. Replace the element
3. Soft solder the element
4. Silver solder the element

4-29. How should you make emergency repairs to a leaky tube of a shell in a tube-type oil cooler?

1. Plug the tube at both ends with a special plug
2. Plug the tube at both ends with a strip of neoprene
3. Seal the tube with soft solder
4. Seal the tube with solder at the inlet end only

4-30. Shell-and-tube-type heat exchangers are cleaned by which of the following methods?

1. Air lances, steam sprays, or chemical solutions
2. Steam sprays or chemical solutions only
3. Air or water lances only
4. Chemical solutions, air lances, or water lances

Learning Objective: Recognize casualties pertaining to lubricating systems and point out how they may be avoided.

● Question 4-31 is to be judged True or False.

4-31. If you will use the proper type of lube oil in an engine lubricating oil system you will ensure that all engine parts receive sufficient lubrication.

4-32. Pressure in the lubricating system is maintained by which of the following devices?

1. Relief valves
2. External relief valves
3. Internal pressure regulating valves
4. All of the above

4-33. Which of the following conditions indicate a broken lube oil pump?

1. Smoke rising from the shaft
2. Abnormal noise in the pump
3. Sudden increase of lube oil pressure
4. Fluctuation of lube oil pressure

4-34. When is the low-pressure warning device of a lube oi 1 system usually tested?

1. Every day
2. When the system is started and secured
3. Only when the system is started
4. Only when the system is secured

4-35. In addition to temperature and pressure readings, which of the following methods should you use to determine if a bearing is receiving oil?

1. After shutdown, inspect bearings to determine the pressure of the oil
2. After shutdown, place you hand on a bearing to note the temperature
3. Both 1 and 2 above
4. Blow air through lube oil passages

4-36. Which of the following materials should you use when cleaning an engine lube oil sump?

1. Cotton waste
2. Paper towels
3. Lintfree cloths
4. All of the above

4-37. You have removed an oil filter line from an engine. Before reinstalling, the line should be cleared of any obstructions with

1. diesel oil
2. compressed air
3. low-pressure steam
4. freshwater lances

Learning Objective: Explain the operational characteristics of fuel injection equipment and engine controls. Recognize symptoms of fuel injection trouble and their causes, and indicate what corrective measures may be required.

4-38. Regardless of design, under which of the following conditions should solid fuel injection systems deliver the fuel oil to each engine cylinder?

1. At a high pressure
2. In the correct amounts
3. At the proper time
4. All of the above

4-39. What are the two general types of solid fuel injection systems?

1. Unit injection and common rail
2. Jerk pump and common rail
3. Individual pump and jerk pump
4. Unit injection and individual pump

● Question 4-40 is to be judged True or False.

4-40. The pump-injection system that combines a high-pressure pump and fuel injection nozzle into one unit is called a unit injector.

4-41. Which of the following injection systems uses a metering device that delivers the appropriate amount of fuel to each injector?

1. Atlas
2. Cooper-Bessemer
3. Bosch
4. Cummins

4-42. Which of the following factor(s) control(s) the amount of fuel that is injected by the cam-operated injector valves of the basic common-rail injection system?

1. The length of time the nozzle stays open
2. The pressure held by the high-pressure pump in the common rail
3. The action of the individual valves mounted on the side of the engine
4. The length of time the nozzle remains open and by the pressure held by the high-pressure pump in the common rail

● Question 4-43 is to be judged True or False.

4-43. Most diesel injection equipment operating problems are resolved when clean fuel is used.

4-44. Which of the following is the best method to determine whether the bushing assembly of a unit injector has been damaged?

1. Place the injector in a test stand and test the bushing assembly
2. Install the injector in a test engine, operate the engine, and check for low firing pressure
3. Disassemble the injector, clean it, and inspect each part of the bushing assembly
4. Install the injector in a test engine, operate the engine, and check for low exhaust temperature

4-45. Which of the following operations is affected by irregularities in the surface and helix edge of a plunger?

1. Pumping
2. Metering
3. Combustion
4. Firing

4-46. If the lapped surfaces of a plunger and barrel assembly are exposed to atmospheric dust, the surfaces will

1. erode
2. rust
3. score
4. bind

● Questions 4-47 and 4-48 are to be judged True or False.

4-47. Some fuel oil systems have additional safety filters or screens located between the fuel transfer pump and the fuel distributor.

4-48. The absorbent qualities of cotton waste make it an excellent drying agent for fuel injector parts.

4-49. Lapped surfaces should be handled only after they have been

1. allowed to dry at room temperature
2. immersed in clean diesel oil
3. washed in distilled water
4. dried by heat for several minutes

4-50. External leakage of diesel fuel from pumps and injectors is probably caused by which of the following conditions?

1. Loose connections, scored plungers, or cracked housings
2. Scored plungers, improper assembly, or broken springs
3. Eroded bushing ports, loose connections, or broken springs
4. Improper assembly, loose connections, or cracked housings

4-51. On some fuel injection equipment, mild roughness and discoloration of the sealing surfaces may be removed by which of the following methods?

1. Lapping
2. Scrapping
3. Grinding
4. Honing

4-52. When the plunger of the injection pump of a diesel engine is stuck, it usually causes which of the following conditions?

1. Engine failure
2. Excessive fuel consumption
3. Increase in engine temperature
4. Failure of a cylinder to fire

4-53. A binding plunger test is being performed. What kind of trouble is indicated by a sluggish return of the plunger?

1. A broken plunger spring
2. A sticky plunger
3. A nicked plunger
4. A scored plunger

4-54. In trying to loosen a stuck fuel oil injector plunger, you should soak the plunger and barrel in which of the following fluids?

1. Clean diesel fuel
2. Lubricating oil
3. Cleaning solvent
4. Unleaded gasoline

4-55. You are cleaning a Bosch fuel injection pump plunger. What should you do after rinsing it in fuel oil and blowing it dry?

1. Examine the plunger for defects
2. Reassemble the pump assembly
3. Place mutton tallow on the plunger
4. Wipe the plunger with a mild abrasive

4-56. Which of the following materials should NOT be used to free up the plunger and bushing to a G.M. unit injector?

1. Jewelers' rouge
2. Mutton tallow
3. Clean fuel oil
4. Compressed air

4-57. In a diesel engine fuel system, what is the function of the fuel control rack?

1. To control vaporization of fuel
2. To remove impurities from the fuel
3. To meter the fuel injected at each stroke
4. To prevent jamming of the fuel injector plunger

4-58. Which of the following conditions causes an engine fuel oil control rack to stick?

1. End play
2. Normal wear
3. Gear backlash
4. Dirt in the mechanism

4-59. What effect, if any, may backlash in the control rack have on engine performance?

1. High exhaust temperature
2. Low firing pressures
3. Variations in speed
4. None

4-60. Backlash in the fuel control system is often caused by which of the following parts?

1. Jammed control rack
2. Scored pump plunger
3. Distorted pump bushing
4. Worn control sleeve

Learning Objective: Discuss the operational characteristics of fuel injection equipment and engine controls. Recognize symptoms of fuel injection troubles, as well as their causes, and indicate corrective measures that may be required.

● Question 4-61 is to be judged True or False.

4-61. Improper seating of the exhaust valves may cause symptoms similiar to improper timing of the engine fuel injection system.

4-62. Late timing of fuel being injected into a cylinder may be indicated by which of the following conditions?

1. Engine detonation
2. Injection pump, leakage
3. High exhaust temperature
4. Low exhaust temperature

4-63. Which of the following factors may be the cause for a Bosch fuel injector pump to go out of timing?

1. A broken spring
2. A stuck plunger
3. A worn pump camshaft
4. An eroded spill port

4-64. Which of the following corrective measures could you use to reduce the number of engine governor difficulties?

1. Reduce the engine speed
2. Increase the engine load
3. Use clean oil
4. Adjust the fuel linkage

● Questions 4-65 and 4-66 are to be judged True or False.

4-65. To maintain the proper oil level in the engine governor, you may use lubricating oil from the main diesel engine crankcase.

4-66. Foaming of the oil indicates presence of water in an engine governor.

4-67. When the governor compensating needle valve is correctly adjusted, how should the engine behave during load changes?

1. Maintain low underspeeds
2. Maintain high overspeeds
3. Return slowly to normal speeds
4. Return quickly to normal speeds

4-68. An increase in load for any constant throttle setting of a mechanical governor will be accompanied by a decrease in

1. engine speed
2. spring length
3. fuel pressure
4. oil temperature

● Question 4-69 is to be judged True or False.

4-69. Hydraulic rather than mechanical governors are used where extremely accurate engine speed regulations are required.

4-70. What type of governor is designed to hold the predetermined operating speed of a diesel engine generator set?

1. Load-limiting
2. Variable-speed
3. Speed-limiting
4. Constant-speed

4-71. The mechanical governor controls engine idling speed when the centrifugal force of both sets of flyweights act against which of the following parts?

1. The buffer spring
2. The light spring
3. The heavy spring
4. All of the above

4-72. Which of the following conditions may cause an improper speed fluctuation of an engine equipped with a mechanical governor?

1. Constantly changing loads
2. Misfiring engine cylinders
3. A binding governor linkage
4. Each of the above

4-73. An overspeed trip will stop a diesel engine that is equipped with a speed governor when the regular speed governor fails to

1. limit the load on the engine
2. keep the engine within its maximum designed limit
3. operate
4. reduce engine hunt

● Question 4-74 is to be judged True or False.

4-74. Prior to testing the engine overspeed trip, the accuracy of the engine tachometer should be checked for proper operation as required by the manufacturer's instructions.

4-75. A broken drive shaft of a hydraulic overspeed trip will cause uncontrolled engine speed because the flyweights

1. disconnect from the shaft
2. remain in a distended position
3. cease to exert centrifugal force
4. increase in rotative speed

Assignment 5

Engine Maintenance (cont'd)

Textbook Assignment: Engineman 1&C, NAVEDTRA 10543-E1, Pages 3-25 through 3-41

Learning Objective: Describe the types of piston and rod assemblies used in internal combustion engines, recognize symptoms of malfunctions and their causes, and indicate the type of actions that may prevent the recurrence of such troubles.

- Question 5-1 is to be judged either True or False.

5-1. Before attempting to jack an internal combustion engine over by hand, you should first disable the starter circuit.

5-2. Which of the following symptoms indicate(s) that the clearance between the piston and cylinder is above tolerance?

1. Excessive oil consumption
2. Piston slap after top dead center
3. Piston slap after bottom dead center
4. All of the above

5-3. On Navy engines, piston defects are NOT likely to be caused by which of the following conditions?

1. Unbalanced load
2. Insufficient lubrication
3. Crown and land dragging
4. Excessive piston liner clearance

5-4. Operation of an internal combustion engine above the specified temperature limits may result in which of the following problems?

1. No lubrication of the cylinder walls
2. Low cylinder temperatures
3. Increased oil viscosity
4. High oil temperatures

5-5. If the oil flow to a piston is restricted, where will the oxidation of the oil cause deposits to form?

1. On the underside of the piston crown
2. Behind the compression rings
3. On the piston walls
4. On the piston crown

5-6. When the clearance between the piston and the cylinder liner is too small, the piston will NOT likely

1. seize
2. bind
3. break
4. wear in

5-7. The wiping of metal causes the rings to stick in the piston grooves. What is this action called?

1. Scoring
2. Scuffing
3. Calling
4. Wiping

5-8. Which of the following actions is/are required to balance the load on each piston of an auxiliary generator diesel engine?

1. Setting the fuel rack
2. Checking the compression pressures
3. Checking the firing pressures
4. All of the above

5-9. Cracking of the ring groove lands on a piston can be attributed to which of the following conditions?

1. Excessive piston-to-cylinder clearance
2. Insufficient clearance between the ends of the rings
3. Insufficient ring-to-land clearance
4. Each of the above

5-10. Which of the following corrective actions is recommended for pistons that are excessively worn?

1. Plating the piston
2. Replacing the piston
3. Resizing the piston
4. Metal spraying the piston

5-11. Which of the following conditions may cause low compression pressures that might affect several or all cylinders of an auxiliary diesel engine?

1. A leaking cylinder valve
2. A clogged air filter
3. A clogged intake port
4. A leaking after-chamber

5-12. Which of the following factors may cause excessive oil consumption during engine operation?

1. Worn oil rings
2. Use of improper oil
3. High lube oil temperatures
4. Each of the above

5-13. Which of the following symptoms may be indicative of excessively worn piston rings?

1. High compression
2. Hard starting
3. Clear exhaust
4. All of the above

5-14. Carbon deposits that limit the flexing movements of piston rings are usually formed when an engine is operated under which of the following conditions?

1. Excessive operating temperatures
2. High cooling temperatures
3. Improper balance
4. Improper load

5-15. Which of the following factors may cause a piston ring to extend into a port of a ported cylinder?

1. Excessive engine speeds
2. Insufficient gap clearance
3. Insufficient ring pressure
4. Excessive operating temperatures

5-16. When a piston ring breaks because of insufficient end gap, it will have (a) bright spot(s) on what part(s) of the ring?

1. Upper side
2. Lower side
3. Ends
4. Face

5-17. When fitted to a liner, if a piston ring lacks sufficient pressure to return to its original shape, what is the ring likely to do?

1. Wear in place
2. Seize and buckle
3. Bind in the groove
4. Break under pressure

5-18. Which of the following conditions probably causes the greatest amount of wear on piston rings?

1. Worn cylinder liners
2. Abnormal carbon deposits
3. Insufficient gap clearance
4. Excessive operating temperatures

5-19. Which of the following positions is recommended for piston ring gaps in order to allow for cylinder wear?

1. All gaps in line with the piston bosses only
2. All gaps 90° out of line with the piston bosses
3. All gaps staggered alternately 90° with the piston bosses
4. All gaps in line with the piston bosses and alternate rings staggered 180°

5-20. A ridge in a cylinder liner must be removed when piston rings are replaced in order to prevent the

1. bottom ring from cracking
2. top ring from slipping down
3. top ring and the land from breaking
4. rings from slipping too close together

5-21. If you want to determine the amount of wear on a piston assembly, you should measure only those areas that

1. make contact
2. are scored
3. appear to be worn
4. are pitted

5-22. Which of the following means are used to lubricate piston pin bushings?

1. Splash oil
2. Pressure oil
3. Mechanical oilers
4. Oil rings

5-23. The interchangeability of piston-pin bushing inserts is dependent on the location of the

1. oil holes
2. piston pin
3. needle bearing
4. pin bushing

5-24. Primarily, why are piston pin bushings reamed?

1. To obtain larger oil holes
2. To obtain correct lubricating flukes
3. To obtain proper bore clearance
4. To correct oil hole positioning

5-25. Which of the following troubles can be caused by misalignment of the connecting rod?

1. Binding of the piston
2. Binding of the piston pin
3. Binding of the connecting rod journal bearing
4. All of the above

5-26. Which of the following tools should you use to prevent overtightening of connecting rod bolts?

1. Socket wrench
2. Torque wrench
3. Strain gauge
4. Thickness gauge

5-27. Which of the following connecting rod troubles is likely to occur because of overstress?

1. Cracked rods
2. Misaligned rods
3. Out-of-round bearing bores
4. Plugged oil passages in the rods

● Question 5-28 is to be judged True or False.

5-28. You should repair by welding or brazing any cracked connecting rods discovered during engine overhaul.

Learning Objective: Point out some of the causes of engine shaft and bearing failure and indicate methods of reducing the most commonly encountered troubles

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5-29. What is the usual cause of fatigue failure of the crankshaft journal bearings?

1. Loose bearing shells
2. Improper lubrication
3. Cyclic peak loads
4. Each of the above

5-30. What effect will extreme overspeeding of an internal combustion engine have on the main journal bearings?

1. Failure of the upper halves only
2. Failure of the lower halves only
3. Either 1 or 2 above
4. Failure of both the lower and the upper halves

5-31. Which of the following factors could be the cause of crankshaft fatigue failure?

1. Improper functioning of the vibration damper
2. Improper quenching or balancing by the manufacturer of the crankshaft
3. Flexing of the crankshaft under load
4. All of the above

5-32. The crankshaft of a reciprocating engine may be responsible for which of the following conditions?

1. Lineal impulses
2. Natural vibrations
3. Torsional impulses
4. Natural frequencies

● Questions 5-33 and 5-34 are to be judged True or False.

5-33. The term "critical speeds" applies to all moving members of machinery with the exception of reciprocating-type engines.

5-34. Continuous engine operation within the critical speed range may result in breakage of the crankshaft and connecting rod bearing difficulties.

5-35. Assume a propulsion diesel engine has a tachometer with the area between 700 rpm and 750 rpm conspicuously marked in red. The speeds within this range are the

1. maneuvering engine speeds
2. critical engine speeds
3. most efficient operating speeds
4. smoothest operating speeds

5-36. To reduce torsional fluctuations and ensure smoother operation, some diesel engine crankshafts are equipped with which of the following devices?

1. Vibration dampers
2. Flexible couplings
3. Shock absorbers
4. Flywheels

5-37. Which of the following lubricants is/are harmful to the rubber of elastic-type vibration dampers?

1. Lube oil
2. Diesel oil
3. Light grease
4. All of the above

5-38. Which of the following engine noises indicates an improperly functioning vibration damper?

1. Grinding noises at low speeds
2. Clinking noises during starting
3. Rumbling noises at normal speeds
4. Humming noises at high speeds

● Question 5-39 is to be judged True or False.

5-39. Crankshaft failure may result from excessive main bearing clearances that allow an uneven distribution of the engine load during operation.

5-40. You can help keep engine journal bearings from wearing out-of-round by preventing which of the following conditions?

1. Inadequate lubrication and journal bearing failure
2. Overloading or overspeeding of the engine
3. Excessive crankshaft deflection and misalignment of parts
4. All of the above

5-41. Which of the following actions is likely to cause excessive crankshaft deflection?

1. Overloading
2. Overspeeding
3. Insufficient lubrication
4. Excessive operating temperatures

5-42. What valve assembly trouble is likely to score the camshaft cams of an engine?

1. A worn rocker arm bushing
2. A broken tapped screw
3. A chipped valve spring
4. An improperly seated push rod spring

5-43. Which of the following inspections to the valve actuating linkage should be made at frequent intervals during engine operation?

1. Inspections for improperly seated valve springs
2. Inspections for grooved or scored cam follower surfaces
3. Inspections for improperly seated push rod end fittings
4. All of the above

5-44. What is the danger in using an engine lubricating oil that has a viscosity higher than recommended?

1. Rapid absorption of acids
2. Rapid absorption of carbon particles
3. Surface pitting of bearings
4. Overlubrication

● Question 5-45 is to be judged True or False.

5-45. When a bearing fails because of an inadequate bond between the bearing metal and the bearing shell, the bearing shell shows through the bearing surface.

5-46. Crankshaft journals that exceed the specified tolerances for out-of -roundness should be refinished by which of the following means?

1. Stoning
2. Grinding
3. Filing
4. Scraping

5-47. A rough spot or ridge located on a crank pin journal should be removed by dressing with which of the following materials?

1. 4 fine sandpaper
2. A crocus cloth
3. A fine oil stone
4. Both 2 and 3 above

5-48. What damage may result to a crank pin bearing when the piston bushing bore and connecting rod bore are not in alignment?

1. Cracking at the opposite ends of the lower and upper halves
2. Cracking at the same ends of the lower and upper halves
3. Wiping at the opposite ends of the lower and upper halves
4. Wiping at the same ends of the lower and upper halves

5-49. What is indicated when the back of a bearing shell contains a gumlike varnish deposit?

1. Excessive bearing clearance
2. Normal bearing wear
3. Low operating temperatures
4. Lack of lubrication

5-50. If the lower shell of a journal bearing is interchanged during installation with a plain upper shell, what, if anything, happens to the oil flow in the bearing?

1. It decreases
2. It increases
3. It stops
4. Nothing, it remains the same

5-51. Bearing lubrication is poorest when the engine is being

1. overloaded
2. idled
3. started
4. stopped

5-52. What is the purpose of motor-driven lube oil pumps used on diesel engines?

1. To increase the pressures obtainable from the engine-driven pumps
2. To service the engine gear training and bearings during normal operation
3. To lubricate the bearings before engine operation
4. To increase the flow during engine operation

5-53. In order to check for abrasive elements in the lubricating oil of an engine, the oil samples should be obtained regularly from which of the following sources?

1. The most accessible point in the lube oil system
2. The lowest point in the sump
3. The oil filter element
4. The lube oil pump

5-54. What part of a frictionless bearing should you inspect for signs of pitting and surface cracks?

1. Inner surface of the inner race
2. Outer surface of the inner race
3. Inner surface of the outer race
4. Outer surface of the outer race

5-55. Which of the following actions may cause dented races in the antifriction bearings that support heavy shafts?

1. The application of too much pressure when the bearings are installed
2. The application of too much pressure when the bearings are removed
3. The application of vibration to the bearings when the shafts are idle for a long time
4. Each of the above

5-56. A frictionless bearing is always replaced when an inspection reveals which of the following problems?

1. It is difficult to operate by hand
2. It has brinelled races
3. It operates noisily
4. It is dirty

5-57. Only one race of an antifriction bearing is made a press fit because it is highly desirable to have the other race

1. abrade
2. creep
3. removable
4. unloaded

- Questions 5-58 and 5-59 are to be judged True or False.

5-58. The only way to tell if a bearing has a cracked race is by a visual inspection.

5-59. The best way to determine if excessive looseness exists in a frictionless bearing is to compare the bearing suspected of being loose with d new bearing.

5-60. What is the probable cause of looseness in an oiled roller bearing?

1. Improper adjustment
2. Improper installation
3. Abrasives in the oil
4. Faulty oil seal

Learning Objective: Recognize the purpose and types of auxiliary drive mechanisms; and specify the general inspection and maintenance requirements.

5-61. What is the purpose of the chain drive mechanism that drives the blower on a diesel engine?

1. To reduce the speed of rotation of the blower
2. To increase the speed of rotation of the blower
3. To time the operation of the blower in the correct sequence of events with the operation of the engine
4. To prevent overspeeding of the blower

5-62. What gears are used in the gear train for the auxiliary mechanisms of most internal combustion engines?

1. Bevel gears
2. Single helical spur gears
3. Double helical spur gears
4. Worm gears

5-63. Most internal combustion engine drive gears are constructed of which of the following materials?

1. Steel
2. Cast iron
3. Bronze
4. Fiber

5-64. What is the function of idler gears in a timing train?

1. To reduce the speed of the camshaft
2. To increase the speed of the camshaft
3. To reduce vibrations in the gear train
4. To transfer the rotation of the crankshaft over a considerable distance

5-65. What is the speed of the camshaft in a four-stroke cycle engine when the crankshaft is turning 920 rpm?

1. 230 rpm
2. 460 rpm
3. 690 rpm
4. 920 rpm

● Question 5-66 is to be judged True or False.

5-66. A longitudinal movement may be produced by an operating gear in a train that is secured with a loosely fitted woodruff key.

5-67. What is the purpose for marking the teeth in an engine gear train as shown in figure 3-24 of your textbook?

1. To indicate the gear diameters
2. To provide a means for mating the gears
3. To identify the size of the gear teeth
4. To indicate the number of gear teeth

5-68. If the bushing clearances on the timing gear train exceed the allowable limit, the bushings should be

1. aligned
2. adjusted
3. reshimmed
4. renewed

5-69. If the only defect found in the auxiliary drive gears is a chipped gear tooth, which of the following actions should you take?

1. Rebuild the tooth by welding
2. Smooth the chipped area by filing
3. Replace the gear
4. Realign the gear

5-70. When the backlash of a blower rotor gear set exceeds the manufacturer's specified limit, what must you do?

1. Replace the gears
2. Replace the rotors
3. Retime the gears
4. Reshim the rotors

5-71. Excessive backlash of the blower rotor drive gears may cause scoring of which of the following parts?

1. Blower casing
2. Shim plates
3. Shaft seals
4. Blower lobes

5-72. An estimate of the life of a Roots blower rotor gear can be determined by which of the following methods?

1. A comparison of charts showing the average use and wear with records of the use of the particular machine
2. 4 careful study of records of the amount of wear as recorded periodically
3. A study of the manufacturer's estimates of lifetime of the gear for the engine
4. A computation of the amount of use the machine will receive and the type of gear used

5-73. When one of the blower rotor drive gears indicates a slight tooth fracture, what should you do?

1. Replace the gear with one from another set
2. Replace the gears with a matched set
3. Align the gears to prevent further damage
4. Install additional shims to relieve tooth contact

5-74. Failure of a properly aligned and adequately lubricated chain drive mechanism may be caused by which of the following parts?

1. Sheared cotter pins
2. Binding joint pins
3. Both 1 and 2 above
4. Worn chain links

5-75. After a long period of operation, how is a chain drive usually adjusted?

1. By peening the connecting link pins
2. By tightening the chain tension
3. By replacing the connecting pin
4. By realigning the idler gears

Assignment 6

Engine Maintenance (cont'd); Reduction Gears and Related Equipment

Textbook Assignment: Engineman 1&C, NAVEDTRA 10543-E1, Pages 4-1 through 4-11

Learning Objective: Recognize conditions which may affect reduction gear operations and the necessary corrective actions to be taken.

6-1. Under normal conditions, which of the following activities effects repairs to the main reduction gears?

1. Ship's force
2. Repair ships
3. Manufacturer
4. Naval shipyards

6-2. To ensure that gears are properly lubricated, an engineman must ensure that which of the following conditions are met?

1. The oil is clean
2. The oil is kept at the correct temperature
3. The proper amount of oil is supplied to the gears and bearings
4. All of the above

● Question 6-3 is to be judged True or False.

6-3. The reduction gear manufacturer designates the exact relief valve settings and pressure to be maintained in the lubrication system to ensure an adequate supply of oil to the gears and bearings.

6-4. What is the likely result of delivering too little or too much oil to a bearing?

1. An overheated bearing
2. An underheated bearing
3. A drop in oil pressure
4. A drop in oil temperature followed by a sharp rise in pressure

6-5. Under any operating condition, what is the maximum permissible temperature rise for oil passing through engine bearings.

1. 50°F
2. 60°F
3. 65°F
4. 70°F

6-6. What is the maximum allowed temperature of the oil leaving any reduction gear or bearing?

1. 165°F
2. 175°F
3. 180°F
4. 195°F

6-7. Fine metal flakes are usually produced during run-in of new gears. These fine metal particles, if not removed from the reduction gear lube oil system, may cause which of the following troubles?

1. Wiped bearings and scored journals
2. Clogged spray nozzles
3. Deteriorated gear teeth
4. All of the above

6-8. Which of the following types of damage to gear teeth surfaces are most likely to result if lubricating oil is contaminated by water?

1. Erosion and corrosion
2. Corrosion and pitting
3. Corrosion and scoring
4. Erosion and scoring

6-9. The journals of the main gear are severely corroded because of lube oil contamination. What repair work should be done as soon as possible?

1. Overhaul of the gears at a naval shipyard
2. Removal of metal flakes from the oil system
3. Realignment of the reduction gears
4. Replacement of the pinion bearings

6-10. How long, after securing the main reduction gear, should you circulate the lubricating oil through the system?

1. 15 minutes
2. Until the temperature of the oil is the same as the reduction gear casing
3. Until the temperatures of the oil and reduction gear casing are approximately the same as the engineroom temperature
4. 30 minutes

6-11. How can you eliminate the condensation of water from the inside of a reduction gear casing?

1. Keep the gear oil heated until condensation evaporates
2. Ensure the gear oil circulates at all times so that the water may be centrifuged out
3. Renovate the gear oil in a purifier while a cooler is operated and the gear is jacked
4. Allow the gear oil to remain unstirred so that water may settle to the bottom of the casing

6-12. Satisfactory operation of which of the following components should keep the lube oil in good condition?

1. Centrifuge and blower
2. Strainer and filter
3. Spray nozzles and heater
4. Purifier and settling tanks

● Question 6-13 is to be judged True or False.

6-13. Reduction gear lube oil samples should be taken and sent to a naval shipyard laboratory only once a quarter to be tested for contamination.

6-14. What substances cause gear lubricating oil to emulsify?

1. Freshwater and seawater
2. Fatty acids
3. Air bubbles
4. Insoluble minerals

6-15. What should be done if the lube oil begins to emulsify?

1. The plant should be stopped and the oil removed
2. The oil should be heated to just below the boiling point
3. The oil should be centrifuged to get rid of the water and the acid
4. The oil should be allowed to settle to get rid of the water and the acid

6-16. Assume that during operation, the lubricating oil level in the sump of the reduction gear rises high enough to come into contact with the bull gear. What is likely to result if this situation is NOT corrected?

1. The oil will overheat
2. The oil will become emulsified
3. The oil will be trapped in the sump
4. The oil will be contaminated with water

6-17. What should you do first in case of a burned-out pinion bearing?

1. Stop the engine
2. Align the gear teeth
3. Stop the main propeller shaft
4. Slow down the engine

6-18. What is the first probable cause to be considered when a vibration occurs in a reduction gear that previously had been operating properly?

1. Bent propeller shaft
2. Bent propeller blade
3. Unbalanced bull gear
4. Misaligned pinion gear

Learning Objective: Explain the methods of checking bearing clearances and identify the main troubles encountered with reduction gear bearings.

6-19. Which of the following information, recorded in prescribed engineering records, should be available for checking the alignment of the reduction gear?

1. Gear teeth root clearances and backlash
2. Thrust bearing clearances and settings
3. Original bearing clearances and crown thickness
4. All of the above information

6-20. Aboard ship, special equipment is usually available to perform which of the following maintenance tasks?

1. Replace bearings
2. Lift reduction gear covers
3. Take readings
4. All of the above

6-21. Which of the following methods is used to check the amount of bearing wear in the main reduction gears?

1. Bridge gage
2. Crown thickness
3. Radial clearance
4. Axial clearance

6-22. The pressure-bearing half of a main reduction gear bearing shell is readily identified by which of the following means?

1. A scribe line on each end of the shell
2. Three scribe lines on each end of the bearing shell
3. The letter A on each end of the shell
4. The letters B, C, and D on each end of the shell

● Question 6-23 is to be judged True or False.

6-23. During the initial alignment, the crown thickness of each reduction gear bearing shell should be measured at each scribe line and the clearance permanently stamped close to each scribe line.

6-24. What action should be taken if a bearing in a main reduction gear wipes during a trial run?

1. The gear and shaft should be operated at reduced speed
2. The gear should be provided with additional lubrication
3. The gear and shaft should be secured
4. The gear should be cooled with water

6-25. Before emergency repairs are to be attempted on the main reduction gear by the ship's force, what factors should be considered?

1. Ship's location and availability of repair activity
2. Ship's operational schedule and capability of personnel
3. knowledge of construction details and manufacturer's instructions
4. All of the above factors

6-26. What action should you take when replacing a wiped outboard pinion bearing in the reduction gear?

1. Compare the crown thickness of the new bearing with the original crown thickness of the old bearing
2. Compare the new bearing and the old bearing with the manufacturer's specifications
3. Accomplish 1 and 2 above
4. Measure the crown thickness of the new bearing and stamp it just prior to installation

6-27. Assume that you are installing a new bearing. When is the bearing cap lowered into place and bolted down?

1. After the lower bearing half is rolled into position
2. After the upper bearing half is placed in position
3. After the bearing and the dowel are in proper positions
4. After all of the above steps have been accomplished

6-28. If a pinion bearing fails, the shaft at that end tends to

1. move toward the bull gear
2. become scored and pitted
3. move away from the bull gear
4. become cracked and chipped

6-29. After a loss of lubricating oil casualty has occurred to the main reduction gear, what bearings should be checked first?

1. Thrust bearings
2. Pinion bearings
3. Bull gear shaft bearings
4. Main propulsion shaft bearings

6-30. What precautions must you observe when working around or inspecting an open reduction gear?

1. All tools must be secured with a suitable line
2. All loose articles must be taken from the clothing
3. The area around the gears must be covered and clean
4. All of the above

Learning Objective: Recognize the importance of proper gear tooth clearance and contact; describe the methods used to check clearances and tooth contact; and indicate what corrective action may be necessary.

6-31. Which of the following situations requires that a main reduction gear be given a wearing-in run before being run at full power?

1. New bearings have been installed
2. Old bearings have been resurfaced
3. The gears have been realigned
4. The gear teeth have been stoned

6-32. In main reduction gears, why is it necessary to align gears and provide for the proper clearances?

1. To ensure uniform distribution of pressure over the total area of the tooth faces
2. To prevent dirt and foreign matter from entering the gears
3. To ensure the proper appearance of the gears
4. To ensure that the proper oil pressure is maintained

6-33. When the original tooth contact is destroyed, what type tooth contact takes place?

1. Rolling
2. Metallic
3. Rubbing
4. Sliding

- Question 6-34 is to be judged True or False.

6-34. Initial pitting of new gears may develop during the wearing-in. Slight pitting does NOT affect the operation of the gears.

6-35. In reduction gears, the lead wire method is most useful in measuring the

1. depth of oil clearance
2. extent of bearing wear
3. designed root clearance
4. irregularity of the bearing wear

- Question 6-36 is to be judged True or False.

6-36. Noisy operation and insufficient contact of the reduction gear teeth may result unless the gear and pinion are properly aligned.

6-37. When you are checking the length of tooth contact between reduction gear pinions and gears, which of the following substances is recommended for metal coating?

1. Potassium permanganate
2. Zinc chromate
3. Prussian blue
4. Either 2 or 3 above

6-38. Roughened gear teeth may be stoned smooth provided the deterioration is due to which of the following actions?

1. Destructive pitting
2. Foreign particles
3. Initial pitting
4. Backlash

6-39. How should the high part of a reduction gear tooth be checked?

1. By inserting a feeler gauge between the teeth
2. By inserting a soft plastic wire between the teeth
3. By spotting-in with bluing
4. By taking leads

6-40. What percentages of the working surface of a reduction gear tooth must show contact to indicate a satisfactory tooth bearing?

1. 95 percent of the axial length and 80 percent of the width
2. 80 percent of the axial length and approximately 100 percent of the width
3. 100 percent of the axial length and 75 percent of the width
4. 75 percent of the axial length and 100 percent of the width

6-41. What method should be used to remove a high spot or deformation on a reduction gear tooth?

1. Scraping
2. Stoning
3. Lapping
4. Filing

Learning Objective: Indicate the function of a main thrust bearing and the methods used to check end play of a shaft.

6-42. In a Kingsbury type thrust bearing, which of the following is one of the purposes of the shoe?

1. To equalize the thrust load
2. To transmit the thrust from the collar
3. To hold the leveling plates in place
4. To receive the thrust from the leveling plates

6-43. Some thrust bearing installations are furnished lubricating oil by the same system that lubricates which of the following parts?

1. Main shaft bearings
2. Stern tube bearings
3. Reduction gears
4. All of the above

6-44. Why are Kingsbury thrust bearings usually provided with shoes on each side of the collar?

1. To permit ahead and astern operations
2. To prevent overloading of the oil film
3. To compensate for small errors in alignment
4. To distribute the thrust evenly to all parts of the bearing

6-45. That part of the Kingsbury thrust bearing that tilts to permit the formation of a wedge-shaped film of oil is known as the

1. collar
2. lower leveling plate
3. dowel disk
4. shoe

6-46. When the end play of a Kingsbury thrust bearing is measured, the upper half of the bearing must always be bolted down to prevent which of the following conditions?

1. Breaking of the leveling plates
2. Tilting of the base rings
3. Distortion of the shaft
4. Dislocation of the collar

6-47. What parts of a new thrust bearing are permitted to have a slight displacement from the installed position after the bearing has been put into operation?

1. Leveling plates
2. Base rings
3. Thrust shoes
4. Thrust collars

6-48. In a Kingsbury thrust bearing, if you notice an increase in end play of the main thrust bearing, which of the following parts should you examine first?

1. The main shaft coupling
2. The gear teeth surfaces
3. The thrust shoe surfaces
4. The thrust leveling plates

6-49. Before the end play of a main thrust bearing is measured with a dial indicator, the flange surface should be coated with which of the following substances?

1. Oil
2. Paint
3. Prussian blue
4. Tallow

6-50. When checking shaft end play by jacking on the shaft flange, which of the following actions should you take?

1. Rotate the shaft manually
2. Ensure that no structural damages occur
3. Ensure that the shaft movement has plenty of play
4. Both steps 2 and 3 above

Learning Objective: Recognize the components that support the main propulsion shaft and describe their functions.

6-51. What is/are the primary function(s) of the main line shaft bearings?

1. To support the weight of the shafting and hold it in alignment
2. To link the strut tube with the main line shaft
3. To reduce the amount of friction created during operation
4. To prevent the engine from hunting

● Question 6-52 is to be judged True or False.

6-52. Main line shaft spring bearings are lubricated by brass oiler rings passing around an oil reservoir.

6-53. The following statements concern the main propulsion thrust bearing and a main propeller spring bearing. Which statement is correct?

1. Both bearings are lubricated by the main lubricating oil system
2. The former is lubricated by the auxiliary machinery lubricating oil system and the latter by an independent oil system
3. Both bearings are lubricated by the same independent oil system
4. The former may be lubricated by the reduction gear oil system and the latter by an independent oil system

6-54. How often should personnel of a ship in an operating status check the main propulsion shaft bearing lube oil supply levels and temperatures?

1. Daily
2. Twice a day
3. Once during a watch
4. Hourly

6-55. How often should main shaft spring bearing clearance readings be taken?

1. Monthly
2. Quarterly
3. Semi-annually
4. Yearly

6-56. The area between the rotating propeller shaft and the stern tube is sealed by which of the following devices?

1. Fairwater sleeve
2. Stern-tube gland
3. Bearing bushing
4. Bulkhead gland

● Question 6-57 is to be judged True or False.

6-57. A firemain connection is fitted to the forward space of the stuffing box for the purpose of maintaining a positive flow of water through the stern tube.

6-58. Which of the following materials is used to prevent excessive leakage of seawater into the ship through the stern tube?

1. Carbon
2. Rubber
3. Babbitt
4. Flax

6-59. Which of the following types of bushings are usually found on strut bearings?

1. Lignum vitae
2. Laminated resin-bonded
3. Rubber
4. All of the above

Assignment 7

Reduction Gears and Related Equipment (Cont'd); Engine Performance and Efficiency

Textbook Assignment: Engineman 1&C, NAVEDTRA 10543-E1, Pages 4-12 through 5-10

Learning Objective: Recognize the components of the controllable pitch propellers and their operating principles.

7-1. In a CRP system, which of the following component(s) form(s) the chamber for the servomotor piston?

1. Hub cone and end cover
2. Hub cone and hub body
3. Head tank
4. Tailshaft

● Question 7-2 is to be judged True or False.

7-2. The hub is secured to the tailshaft by flange bolts which are designed to take torque from the tailshaft.

7-3. To which of the following components are the propeller blades attached?

1. Hub body
2. Bearing ring
3. Crank pin ring
4. Guide pin dowels

7-4. Where is the valve rod assembly located?

1. In the hub
2. In the servomotor
3. In the shaft alley
4. Within the propeller shaft

7-5. From which of the following sources is the hydraulic oil supplied to the hydraulic oil pumps?

1. Engine sump
2. Reduction gear
3. Separate sump
4. Hub oil tank

In answering questions 7-6 through 7-10, select from column B the component of the CRP propeller system that is being described in column A.

A. Description	B. Component
7-6. Provides a direct hydraulic oil connection to the main propulsion shaft	1. OD box
7-7. Contains the major components of the hydraulic system	2. Standby PumP
7-8. Provides a mechanical link between the OD box and the hub servomotor	3. Valve rod assembly
7-9. Mounted at the forward end of main reduction gear housing and driven through a disconnect coupling.	4. Hydraulic oil power module
7-10. Translates to the valve rod in response to control oil commands	

● Question 7-11 is to be judged True or False.

7-11. The primary function of the standby pump is to serve as a backup pump in case of main pump failure.

7-12. When the C/P unit is stabilized, where does the standby pump discharge the oil?

1. To the servosystem
2. To the gravity tank
3. To the lower oil tank
4. To the upper gravity tank

7-13. What is the main purpose of the upper gravity oil tank?

1. To recycle the control oil
2. To act as a backup to the CRP system
3. To maintain a static head pressure on the hub
4. To serve as a ready reserve to the OD box

Learning Objective: Indicate the procedures to follow when inspecting gears and related equipment.

7-14. Before any inspection plate to the main reduction gear is lifted or opened, permission must first be obtained from which of the following personnel?

1. Commanding officer
2. Main propulsion officer
3. First lieutenant
4. Engineer officer

7-15. Assume the main reduction gear inspection plates are opened to check the tooth contact of the pinions and bull gear. What information should be entered in the Engineering Log after the inspection plates are secured?

1. The name of the officer who witnessed the closing of the inspection plates
2. The statement that the inspection showed no foreign matter had entered the casing
3. The statement that the inspection showed that the oil-spray nozzle lines were open and clear of any obstructions
4. All of the above

7-16. Reduction gear inspection plates should be opened and the gears and oil-spray nozzles inspected at least once each

1. week
2. month
3. quarter
4. year

● Question 7-17 is to be judged True or False.

7-17. A 7-year inspection of the main reduction gear should be requested and the necessary repairs conducted by a naval shipyard if alignment trouble is suspected.

7-18. If a submerged object is struck by a ship's propeller, when should the main reduction gear be inspected?

1. Immediately
2. After the ship is drydocked
3. After the ship is docked or anchored
4. When it shows signs of malfunctioning

7-19. When should the flexible couplings between turbines and reduction gears be inspected?

1. Prior to full power trials
2. After a full power trial
3. Prior to shipyard overhaul
4. During shipyard overhaul

7-20. Which of the following operations is NOT usually carried out just before a full power trial?

1. The opening of the gear casing
2. The inspection of the contact of the gear teeth
3. The checking of the operation of the oil-spray nozzles
4. The inspection of the oil-spray nozzle strainers

7-21. A 2-hour full power trial has just been completed and you are directed by proper authority to check the main gear. Which of the following actions will you take?

1. Inspect the main thrust bearing clearance
2. Inspect the gear tooth contact
3. Inspect the condition of the gear teeth
4. Each of the above

Learning Objective: Point out the safety precautions which are applicable to reduction gears, shafts, and bearings.

7-22. What must you do if the bull gear churns and aerates the oil?

1. Slow or stop the engine until normal conditions are restored
2. Remove some of the oil without changing the engine speed
3. Stop the engine, and drain and replace the oil
4. Stop the engine and add some fresh oil

7-23. Gears should be slowed down or stopped altogether when which of the following conditions occur?

1. Oil is emulsified in the gear case
2. Unusual noises are heard
3. Both 1 and 2 above
4. Bearing temperature are below normal

7-24. When should the main shafts be locked?

1. When the divers are inspecting damaged propellers
2. When strong currents are present at anchorage
3. When the ship is underway
4. At all of the above times

7-25. Which of the following conditions should be in effect when the main shaft of a ship is allowed to trail?

1. The windage temperature in the low-pressure casing is kept at a maximum
2. The lubricating system must be operating
3. The shaft brake must be engaged
4. The turning gear must be engaged

7-26. Which of the following gears must be disengaged before the main engines are started?

1. Reduction
2. Turning
3. Pinion
4. Bull

Learning Objective: Point out factors that affect the power output of an engine and recognize the terms and formulas used in computing engine performance and efficiency.

7-27. Which of the following characteristics will affect the efficiency and performance of internal combustion engines?

1. Engine design
2. Compression ratio
3. Operating temperatures
4. Each of the above

7-28. To calculate the indicated horsepower of an engine, you need to know the indicated mean effective pressure and what other factor?

1. The engine speed
2. The brake horsepower
3. The fuel consumption rate
4. The brake mean pressure

7-29. What is the speed of a piston if the rotation speed of the crankshaft is 1,000 rpm and the piston stroke is 12 inches?

1. 1,260 fpm
2. 2,000 fpm
3. 12,000 fpm
4. 24,000 fpm

7-30. When the engine rpm drops below rated speed, what usually happens to the brake mean effective pressure?

1. It remains the same
2. It decreases
3. It increases
4. It increases and then decreases

7-31. If an engine is operated for long periods at idling speed, how frequently will overhaul be necessary?

1. More frequently than if operated at 50% of load
2. Less frequently than if operated at 100% of load
3. As frequently as if operated at 75% of load
4. Less frequently than if operated at 90% of load

7-32. An unbalanced cylinder load is indicated by which of the following conditions?

1. Black exhaust smoke
2. High exhaust temperatures
3. Low cooling water temperature
4. Low lubricating oil temperature

7-33. What happens to the lubricating oil that leaks past newly installed piston rings into a cylinder?

1. It drains into the sump
2. It burns in the cylinder
3. It collects on the piston crown
4. It passes out of the cylinder into the exhaust

7-34. An unbalanced cylinder will cause which of the following effects?

1. It will gum up the combustion spaces
2. It will score the cylinder wall
3. It will corrode the piston crown
4. It will overheat the engine

7-35. Engine efficiency is measured by the relationship between energy input and what other factor?

1. Temperature of exhaust
2. Amount of fuel consumed
3. Temperature of combustion
4. Amount of power developed

7-36. Compression ratio refers to the relation between the volume of air above a piston when it is at top dead center and what other factor?

1. The volume of air below the piston when it is at top dead center
2. The volume of air above the piston when it is at bottom dead center
3. The pressure of the air above the piston when it is at top dead center
4. The temperature of the air below the piston when it is at bottom dead center

7-37. Why is the efficiency of the Otto cycle less than that of the diesel cycle?

1. Because the Otto cycle reaches a higher temperature
2. Because the Otto cycle has a lower compression ratio
3. Because the Otto cycle uses a greater amount of air
4. Because the Otto cycle uses a smaller amount of air

7-38. Assume that an engine has an indicated horsepower of 1,600 and uses 400 pounds of fuel per hour. If the fuel has a value of 20,000 Btu per pound, what is the indicated thermal efficiency of the engine?

1. 40.9%
2. 49.4%
3. 50.9%
4. 53.2%

7-39. If an engine consumes 70 pounds of fuel in an hour and the fuel has a potential energy of 20,000 Btu per pound, what is the potential power of the engine? (Use the factor of 2545 Btu per hr/hp.)

1. 36.4 hp
2. 55.0 hp
3. 363.6 hp
4. 550.1 hp

7-40. The overall thermal efficiency of an engine is 50 percent and the brake horsepower is 1,450.00 Btu per hour. What is the value of the heat input of fuel?

1. 725,000 Btu per hr
2. 1,450,000 Btu per hr
3. 2,000,000 Btu per hr
4. 2,900,000 Btu per hr

7-41. Which of the following factors has the greatest effect on the mechanical efficiency of an engine?

1. Vaporization
2. Corrosion
3. Friction
4. Combustion

7-4 2. What is the relationship between the amount of friction between the moving parts of an engine and the speed of the engine?

1. Friction increases at high speeds
2. Friction decreases at low speeds
3. Friction remains constant throughout the speed range
4. Friction increases at low speeds and decreases at high speeds

● Information for questions 7-43 through 7-53: A 6-cylinder, single-acting, 2-stroke cycle, diesel engine has a mean effective pressure of 104 psi per cylinder when operating at full load and rated speed of 2,500 rpm. The stroke and cylinder bore are 5 inches and 4 inches, respectively. The engine's frictional horsepower is 32 hp and does not change with changes in load or speed. At 2,000 rpm, the brake horsepower for the engine is 166 hp.

7-43. What is the approximate indicated horsepower for the engine at 2,500 rpm?

1. 200 hp
2. 216 hp
3. 232 hp
4. 247 hp

7-44. Under full load at 2,500 rpm, the average pressure exerted on a piston of the engine during each power stroke is

1. 17 1/3 psi
2. 52 psi
3. 104 psi
4. 208 psi

7-45. What effect does a 4-psi drop in cylinder mean effective pressure have on the power developed by the engine at 2,500 rpm?

1. Fewer decreases since cylinder bmep exceeds 100 psi and engine speed drops
2. Power decreases since cylinder temperature drop and quality of combustion is impaired
3. Fewer increases since cylinder bmep exceeds 100 psi and engine speed rises
4. Power increases since cylinder temperature rises and quality of combustion improves

7-46. Which of the following expressions is used to compute brake horsepower at 2,500 rpm?

1. ihp - 32
2. ihp + 32
3. (ihp - 32)ihp
4. (ihp + 32)ihp

7-47. The approximate brake mean effective pressure at 2,000 rpm is

1. 81 psi
2. 87 psi
3. 93 psi
4. 102 psi

7-48. What is the engine's maximum mechanical efficiency?

1. 81.3%
2. 72.4%
3. 87.0%
4. 90.5%

7-49. What is the approximate mechanical efficiency of the engine when operatinq under half load at 2,000 rpm?

1. 72%
2. 81%
3. 84%
4. 87%

7-50. The maximum mechanical efficiency for this engine multiplied by 104 psi should be equivalent to bmep under which of the following conditions?

1. Half load and 2,000 rpm
2. Full load and 2,500 rpm
3. No load and 2,500 rpm
4. No load and 2,000 rpm

7-51. Which of the following factors limit the power that each piston of the engine can develop during a power strike?

1. Frictional heat
2. Scavenge efficiency
3. Heat losses due to incomplete combustion
4. Each of the above

7-52. If the volumetric efficiency of a 4-stroke engine is 50 percent, the amount of air drawn into a cylinder is

1. equal to the amount of air that would enter the cylinder under ideal conditions
2. half the amount of air consumed by combustion
3. half the amount of air that would enter the cylinder under ideal conditions
4. twice the amount of air consumed by combustion

7-53. How is scavenge efficiency of a 2-stroke cycle engine determined?

1. By measuring the air required for combustion
2. By measuring the amount of burned gases removed from the cylinder
3. Both 2 and 3 above
4. By measuring the amount of fresh air entering the cylinder

7-54. The amount of heat lost by an engine cylinder through the exhaust is determined by the temperature in the cylinder

1. when exhaust begins
2. after the charge is drawn in
3. just before compression begins
4. immediately after combustion occurs

7-55. When exhaust valves are timed late, what will be the effect on the operation of an engine?

1. Energy losses will increase due to heat loss
2. The engine will lose pressure before all available work is obtained
3. Insufficient amount air will enter the cylinders for completed combustion of the next charge
4. Both 1 and 3 above

Assignment 8

Refrigeration and Air Conditioning

Textbook Assignment: Engineman 1&C, NAVEDTRA 10543-E1, Pages 6-1 through 7-4

Learning Objective: Indicate how the output of reciprocating refrigeration compressors can be controlled and point out some of the precautions and practices that must be followed when maintaining compressor condensers, and thermostatic expansion valves.

- Question 8-1 is to be judged True or False.

8-1. The output of most high speed reciprocating compressors is controlled by loading and unloading the compressor cylinders.

8-2. In figure 6-8 of your textbook, what will happen when an increase in oil pump pressure causes the piston of the capacity control valve to move against spring A?

1. More cylinders will become loaded and the compressor output increases
2. More cylinders will become unloaded and the compressed output decreases
3. The regulating valves will relieve the oil pressure
4. The compressor output will remain the same

8-3. Which of the following precautions should you take when disassembling and reassembling a compressor unit?

1. Carefully disassemble and remove the parts, noting the correct relative positions so errors will not be made reassembling
2. Make sure that all parts, including those being replaced or reinstalled, are free of dirt and moisture
3. Apply compressor oil freely to all bearings and rubbing surfaces of the parts being replaced or reinstalled
4. Each of the above

8-4. An air compressor has been overhauled. What is the first step you should take to remove the air from a compressor?

1. Disconnect the connection in the discharge gage line between the stop valve and the compressor
2. Disconnect the connection on the compressor suction line
3. Start the compressor and let it run until a vacuum is obtained
4. Remove all oil from the compressor crankcase

- Question 8-5 is to be judged True or False.

8-5. R-12 is an excellent solvent. It has the ability to loosen and remove any foreign matter with which it comes in contact within a refrigeration system.

8-6. In which of the following parts would air that enters a refrigeration plant tend to collect?

1. Upper part of the receiver
2. Upper part of the condenser
3. Inlet end of the condenser
4. Downstream end of the cooling coil

8-7. In a refrigeration system, what is the purpose of the purge valve at the top of the condenser?

1. Take out unpleasant fumes from the refrigerant
2. Vent off excess refrigerant during an emergency
3. Remove any air that may accumulate in the system
4. Permit the opening of the refrigerating system for cleaning and inspecting

8-8. What method should you use to remove foreign deposits from the tubes of a refrigerant condenser?

1. Lance with water only
2. Lance with air only
3. Both 1 and 2 above
4. Wash with acid solution

8-9. On an air-cooled condenser, the exterior surfaces of the tubes and fins are dirty and restricting air circulation. What should be used to clean these surfaces?

1. Jets of steam
2. Hot water lances
3. Compressed air lances
4. Stiff bristled brushes

8-10. How often should the water side of a condenser in a freon system be tested for refrigerant leakage?

1. Daily
2. Weekly
3. Bi-weekly
4. Monthly

8-11. You are testing condenser tubes for leakage. Why do you hold the exploring tube of the leak detector at one end of each condenser tube for about 10 seconds before driving a cork into each end of the tube?

1. To dry the tube heads
2. To detect the presence of R-12
3. To draw fresh air through the tube
4. To vaporize any water left in the tube

8-12. You are attempting to locate leaks in a refrigerator condenser. For what period of time should the condenser be allowed to remain idle after all tubes in the suspected section have been corked, before continuing the test?

1. 2 to 4 hr
2. 4 to 6 hr
3. 6 to 8 hr
4. 8 to 10 hr

8-13. A refrigeration unit is working under a normal heat load and has a sufficient charge of refrigerant. The water side of the condenser should be cleaned if the operating difference between the temperature corresponding to the condensing pressure and the temperature of the outlet circulating water increases above the temperature obtained when the unit was in good condition by how many degrees?

1. 5°F to 10°F
2. 10°F to 20°F
3. 20°F to 30°F
4. 30°F to 40°F

8-14. How does the temperature at the outlet side of the valve compare with the temperature at the inlet side when the thermostatic valve is operating properly?

1. The temperature is lower at the outlet side
2. The temperature is lower at the inlet side
3. The temperature is approximately the same at the outlet and the inlet sides
4. The temperature is higher at the inlet side

8-15. Which of the following factors can cause a thermostatic expansion valve to operate improperly?

1. A collection of dirt on the control bulb
2. A collection of freon at the valve seat
3. A collection of dirt at the valve orifice
4. Each of the above factors

8-16. As a rule, about how many degrees of superheat are picked up by the refrigerant vapor before it leaves the cooling coil?

1. Between 4°F and 12°F
2. Between 15°F and 20°F
3. Between 30°F and 38°F
4. Between 45°F and 50°F

● Question 8-17 is to be judged True or False.

8-17. If you increase the spring pressure of the thermostatic expansion valve to give a high degree of superheat at the evaporator coil outlet, you may cause a low lube oil level in the compressor crankcase.

8-18. In a refrigerant plant, liquid refrigerant may flood back to the compressor from the evaporator if the thermostatic expansion valve is

1. stuck shut
2. adjusted for too high superheat at the outlet
3. adjusted for too low superheat at the outlet
4. reducing the amount of refrigerant flowing into the coil

8-19. If it is suspected that the expansion valve assembly requires replacement, which of the following conditions should be met before an expansion valve test is made?

1. The liquid strainers are cleaned
2. The solenoid valves are operative
3. The system is sufficiently charged
4. Each of the above

8-20. What should a service drum that is used for testing an expansion valve contain?

1. Pressurized R-12
2. Dry compressed air
3. A gas similiar to the one used in the thermal element of the valve
4. Each of the above gasses

● For questions 8-21 through 8-24, assume that you are testing the thermostatic expansion valve of a refrigeration plant.

8-21. When should the thermal element be immersed in a bath of crushed ice?

1. Before the valve inlet is attached to the gas source
2. After the high and low pressure gages have been connected
3. Before the high pressure gage is connected to the valve outlet
4. After the valve on the air supply line has been opened

8-22. A thermostatic expansion valve is set for 5°F of superheat, what should the outlet pressure read on a gage?

1. 16.1 psi
2. 22.5 psi
3. 26.1 psi
4. 32.5 psi

8-23. Which of the following operating conditions is an indication that the expansion valve is seating properly?

1. Low pressure gage stops increasing after a few pounds
2. Low pressure gage continues to increase slowly after a few pounds
3. Either 1 or 2 above happens
4. Low pressure gage increases rapidly and equals the inlet pressure

8-24. You have removed the ice packing from the control bulb. Which of the following outlet pressure conditions indicates that the valve is operating normally?

1. The pressure does not change
2. The pressure decreases rapidly
3. The pressure increases rapidly
4. The pressure decreases a few pounds, then stabilizes

● Question 8-25 is to be judged True or False.

8-25. The entire expansion valve assembly must be replaced when the power element is inoperative.

Learning Objective: Recognize practices that will help assure a properly operating refrigeration and air conditioning system, and identify some of the symptoms that may lead to system failure.

8-26. Under normal operating conditions how full should the receiver of a properly charged refrigeration system be when the compressor stops?

1. 25% full
2. 50% full
3. 85% full
4. 100% full

8-27. During plant operation, which of the following symptoms will indicate a clogged R-12 liquid line strainer?

1. The temperature of the tubing on the outlet side of the strainer is much warmer than the tubing on the inlet side
2. The temperature of the tubing on the inlet side of the strainer is much warmer than the tubing on the outlet side
3. The pressure on the outlet side of the strainer tubing is much higher than on the inlet side
4. The pressure on both the inlet and outlet sides of the strainer tubing are the same

8-28. Which action should you take prior to tightening the cap on a liquid line strainer that has been cleaned?

1. Test the strainer for leaks
2. Open the strainer outlet valve
3. Purge the air out of the strainer
4. Replace the strainer screen spring

8-29. Which of the following conditions may be caused by excessive buildup of frost on the cooling coils?

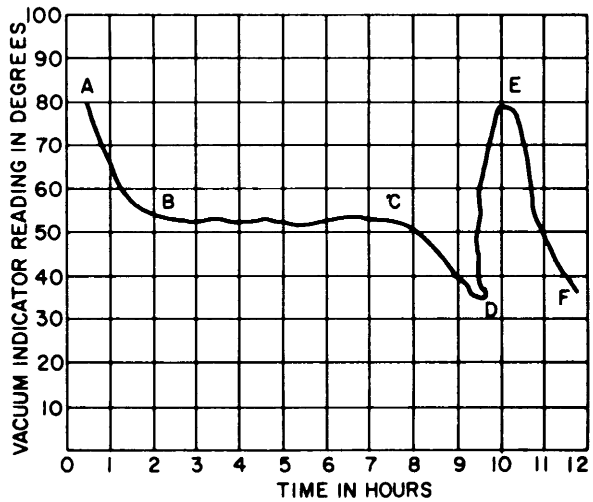
1. Low suction pressure
2. High suction pressure
3. Both 1 and 2 above
4. High condensing pressure

8-30. Which of the following factors help(s) determine the maximum time between defrosting of the cooling coils?

1. Amount of refrigerant in the system
2. Moisture content of the supplies
3. Amount of heat to be removed
4. All of the above

8-31. Cooling coils should be defrosted before the frost thickness reaches

1. 1/4 in.
2. 3/16 in.
3. 1/8 in.
4. 5/16 in.



- Questions 8-32 and 8-33 are based on Figure 8-A.

8-32. Approximately how many inches of mercury represent the difference in temperature between points B and D?

1. 0.200 in. absolute
2. 0.232 in. absolute
3. 0.436 in. absolute
4. 0.640 in. absolute

8-33. Initial evacuation of the refrigerating system begins at point A and is completed at point

1. B
2. C
3. D
4. E

8-34. While you are evacuating and dehydrating a refrigeration system, the vacuum indicator fails to attain 35°F, which of the following conditions may be the cause of this failure?

1. Lack of lubricating oil in the compressor crankcase
2. Lack of moisture in the system
3. R-12 in the lubricating oil
4. Each of the above conditions

8-35. To be properly reactivated, dehydrating agents should be heated to (a) what temperature and (b) for how long?

1. (a) 200°F (b) 12 hr
2. (a) 300°F (b) 12 hr
3. (a) 400°F (b) 6 hr
4. (a) 500°F (b) 6 hr

8-36. If you do not have a tank-type cleaner, you can clean an R-12 system by which of the following means?

1. By flushing boiling water through the system three times
2. By blowing hot air through the system with a blower for 24 hours
3. By inserting a hard wool felt filter in the suction strainer screen and operating the plant with an operator
4. By using any one of the above methods

● Question 8-37 is to be judged True or False.

8-37. The 2 PD air conditioning control may be used where one common cooling coil serves several different spaces.

8-38. How should you clean the sensing elements in humidistats?

1. Use a soft brush
2. Blow gently with air
3. Spray with soap and water solution
4. Use a hard brush

Learning Objective: Recognize troubles that may be encountered with refrigeration and air conditioning systems, and point out corrective measures that may be required.

8-39. What should you do to correct low condensing pressure in an operating refrigeration system?

1. Reduce the water supply
2. Increase the water pressure
3. Clean the valves and the valve nests
4. Adjust the high-pressure cutout switch

8-40. Insufficient refrigerant in a refrigeration plant may cause which of the following problems?

1. High discharge pressure
2. Low suction pressure
3. Frosting of the crankcase
4. High temperature of the overboard water

8-41. Which of the following actions should you take to correct a low condensing pressure in a refrigeration system?

1. Add refrigerant
2. Purge the condenser
3. Increase the compressor speed
4. Adjust the thermostatic expansion valve

8-42. In an R-12 refrigeration plant, what is the probable cause if the compressor runs continuously?

1. An open solenoid valve switch
2. An inadequate supply of refrigerant
3. Clogged condenser tubes
4. An excess of liquid refrigerant

8-43. What are the two symptoms that indicate an inadequate supply of water is passing through the condenser of a refrigeration plant?

1. Excessively low temperature of the overboard water and low discharge pressure
2. High suction pressure and high temperature of the suction line
3. High condensing pressure and compressor short cycling on high pressure switch
4. High suction line temperature and high discharge pressure

8-44. The cut-in point is set too high on the low pressure control switch to an R-12 refrigeration system. How will this affect the functioning of the compressor?

1. The compressor will short cycle
2. The compressor will not operate
3. The compressor will operate unloaded
4. The compressor will operate continuously

8-45. Which of the following conditions is probably caused by an improperly adjusted pressure regulating valve in a refrigeration system?

1. The refrigerant is bubbling
2. The sudden loss of oil from the crankcase
3. The compressor continues to operate unloaded
4. The oil fails to return to the compressor crankcase

Learning Objective: Point out the general practices, maintenance requirements, and tasks necessary for proper operation of air compressors and related system components, and identify the safety precautions to be followed.

8-46. Aboard Navy ships, in which of the following situations would you most likely use HP air?

1. To clean machinery
2. To start diesel engines
3. To operate pneumatic tools
4. Each of the above

8-47. Which of the following statements about general procedures for maintaining air compressors is true?

1. The same procedures are used for low, medium, and high pressure systems except for the additional safety precautions which are observed in caring for high pressure compressors
2. The procedures vary with the type of compressed air system, compressor design, and compressor capacity
3. The procedures are the same for low and medium pressure systems, but for high pressure systems they vary with compressor design and capacity
4. The procedures for low, medium, and high pressure systems made by one manufacturer differ from the procedures used for the systems made by another manufacturer

● Question 8-48 is to be judged True or False.

8-48. Good engineering practice in making repairs is to use the proper tools and to observe all safety precautions and manufacturers' instructions.

8-49. What may be expected when a wrench extension is used to apply more than the specified torque on bolts in order to obtain a tight connection at a gasket joint?

1. Sprung gasketed joints
2. Damaged gaskets, bolts twisted off, and/or insufficient tightness of the joint
3. Either 1 or 2 above
4. Tight joints

8-50. Which of the following statements describes the recommended procedures for cleaning an oil wetted filter element that was removed from a compressor intake?

1. Clean with gasoline or kerosene, dip in lightweight oil, and drain excess oil
2. Clean with steam or strong sal soda solution, dip in clean medium viscosity oil, and drain excess oil
3. Clean with a jet of hot water, dip in kerosene, and drain excess kerosene
4. Clean with kerosene, drain excess kerosene, dip in medium viscosity oil, and drain excess oil

8-51. How is moisture prevented from circulating throughout the air system?

1. By preheating the inlet air
2. By blowing down the compressor inter-coolers
3. By placing coalescent filters in the compressor discharge line
4. By preheating the inter-coolers

● Question 8-52 is to be judged True or False.

8-52. In a two-stage compressor a defective inlet valve in the second stage may be indicated by an increase in the inter-cooler pressure, and a defective discharge valve in the first stage may be indicated by a decrease in the inter-cooler pressure.

8-53. Leakage through the discharge valves of an air compressor is usually caused by which of the following factors?

1. Dirt in the valves
2. Moisture in the air
3. Overcompression of air in the cylinders
4. Insufficient compression of air in the cylinders

8-54. How can you reduce the frequency with which air valve troubles occur or possibly prevent them from occurring?

1. By keeping the pressure high in the intercooler
2. By inspecting and cleaning the valves and the valve passages regularly
3. By periodically circulating high temperature air around the valves
4. By periodically blowing off the valve cover to keep it from becoming too hot

8-55. Carbonized air compressor valves should be cleaned by soaking in

1. gasoline, followed by dressing with emery
2. a solution of kerosene and mineral oil
3. kerosene, followed by a light brushing or scraping
4. a strong soda solution, followed by a stiff brushing

8-56. When you are inserting valves in a compressor cylinder, you should make sure that they open in which direction?

1. Discharge valves open toward the center and suction valves open away from the center of the cylinder
2. Suction valves open toward the center and discharge discharge valves away from the center of the cylinder
3. Discharge valves and suction valves open toward the center of the cylinder
4. Suction valves and discharge valves open away from the center of the cylinder

● Questions 8-57 and 8-58 are to be judged True or False.

8-57. One method of stopping leakage at the threads of the valve setscrew of a high pressure compressor is to wind a piece of wire solder around the threads and tighten the locknut over it.

8-58. The manufacturer's technical manual should contain detailed instructions for the adjustment and maintenance of the various control devices to the air system components.

8-59. What material is used to repack the filter of an air compressor control valve?

1. Wool or sponge
2. Cotton or wool
3. Linen or sponge
4. Nylon or steel wool

8-60. Which of the following components of a compressed air system is vital for its safe operation?

1. Control valve
2. Discharge valve
3. Suction valve
4. Relief valve

8-61. What liquid should be used to fill the sight flow indicator that provides cylinder lubrication to a compressor which uses 9250 Navy Symbol oil?

1. Distilled water
2. Mineral oil
3. Glycerine
4. Each of the above

● Question 8-62 is to be judged True or False.

8-62. The sight flow indicators should be filled with equal parts of glycerine and mineral oil when the machinery cylinders are lubricated with a Navy Symbol 2000 series oil.

Assignment 9

Auxiliary Machinery (continued)

Textbook Assignment: Engineman 1&C, NAVEDTRA 10543-E1, Pages 7-5 through 7-22

Learning Objective: Point out the general practices, maintenance requirements, and tests necessary for proper operation of air compressor components, and identify safety precautions to be followed.

9-1. What is the purpose of the quarterly inspections given the surfaces of air flasks?

1. To detect external corrosion or damage
2. To detect internal corrosion or damage
3. To determine the effectiveness of zinc chromate primer in protecting internal surfaces
4. To determine the effectiveness of zinc chromate primer in protecting internal and external surfaces

9-2. Air system equipment must be drained of excessive moisture and oil deposits at frequent intervals in order to minimize which of the following problems?

1. Internal corrosion
2. Fouling of moving parts
3. The danger of an explosion resulting from oil accumulation
4. Each of the above

9-3. What situation would justify having air flasks inspected prior to the elapse of the normal operating interval between inspections?

1. Major overhaul of the compressor
2. Excess oil being carried into the flask
3. Suspicion of serious corrosion of the air flask
4. Compressor unable to maintain the designed pressure on the flask

- Question 9-4 is to be judged True or False.

9-4. Air flasks should be thoroughly cleaned, inspected, and painted internally with a protective coating of zinc chromate prior to applying a hydrostatic test.

9-5. How often should an idle motor-driven compressor be routinely started and operated?

1. Weekly
2. Monthly
3. Quarterly
4. Semiannually

9-6. Which of the following air compressor tests is normally carried out annually?

1. Capacity test
2. Full pressure test
3. Regulating devices test
4. Starting and operating power test

9-7. Which of the following air compressor tests is normally carried out during a shipyard overhaul period?

1. Capacity test
2. Full pressure test
3. Hydrostatic pressure test
4. Relief valve pressure test

9-8. How often must the air compressor intercooler and aftercooler tube bundles be removed for cleaning?

1. During each shipyard overhaul
2. Quarterly
3. Semiannually
4. Annually

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9-9. By taking which of the following steps can you help prevent an explosion in an air compressor?

1. Ensure that intake air is cool, dry and free of dust
2. Clean intake filters with a strong solution of sal soda
3. Ensure that a relief valve is installed between the compressor and a stop valve
4. All of the above

9-10. What action should you take immediately if air discharged from any stage in a compressor shows an unusual temperature rise?

1. Open the relief valve
2. Secure the compressor
3. Open the pressure gages
4. Check cooling water circulation

9-11. A compressor is to be operated continuously during a 6-week cruise. Which of the following steps should you take to prevent high operating temperatures?

1. Increase water circulation and decrease speed
2. Maintain proper water circulation and operating speed
3. Lift relief valves by hand and relieve pressure
4. Blow down moisture separators and change filters

Learning Objective: Point out the factors that contribute to safe and proper operation of an auxiliary boiler, and specify the symptoms and troubles that may cause faulty operation.

9-12. You are lighting off the auxiliary boiler and the blower does NOT deliver the proper amount of air. Which of the following conditions should you eliminate as a possible cause of the difficulty?

1. Clogged or dirty burner tip
2. Insufficient or fluctuating voltage
3. Bent shaft or slipping V-belts
4. Broken shaft or dirty fan blades

In questions 9-13 through 9-15, which are related to troubleshooting auxiliary boilers, select the condition from column B that may cause the symptom or difficulty listed in column A.

	A. Symptoms or Difficulties	B. Conditions
9-13.	Excessive vibration	1. Dirty or clogged burner tip
9-14.	Feed pump fails to deliver	2. Leak in suction line
9-15.	Ignition failure	3. Fluctuating voltage
		4. Insufficient air to the burner

9-16. Failure of feedwater pumps to deliver water may be caused by which of the following conditions?

1. Malfunction of programming control cams
2. Dynamic unbalance of rotating elements
3. Jammed or worn impellers
4. Each of the above

Learning Objective: Identify boiler water problems, sources of contamination, and boiler water treatment for controlling them.

9-17. In an auxiliary boiler, deposits on the watersides of boiler tubes may cause which of the following problems?

1. Oxidization
2. Vibration
3. Overheating
4. Embrittlement

● Question 9-18 is to be judged True or False.

9-18. In auxiliary boilers, the pH of the boiler water is measured instead of the alkalinity because the higher pH level can be more easily measured by the pH meter test.

9-19. The weight of the boiler water at normal steaming level is 1790.95 pounds. What is its volume in gallons?

1. 300 gal
2. 280 gal
3. 215 gal
4. 84 gal

● In answering questions 9-20 through 9-24 use tables 7-2 through 7-7 and the following information on an auxiliary boiler. Dry weight 11,460 pounds, wet weight 14,250 pounds, operating pressure 125 psi.

9-20. What is the volume in gallons of this boiler?

1. 175 gal
2. 215 gal
3. 300 gal
4. 350 gal

9-21. How many ounces of (a) TSP and (b) DSP are required for the initial chemical treatment for this boiler?

1. (a) 35.5 oz (b) 2.5 oz
2. (a) 35.5 oz (b) 3.5 oz
3. (a) 30 oz (b) 6.5 oz
4. (a) 28 oz (b) 6.0 oz

9-22. How many ounces of (a) TSP and (b) DSP would be required for the initial dosage if the boiler operated at 35 psi?

1. (a) 31.5 oz (b) 6.3 oz
2. (a) 31.5 oz (b) 6.0 oz
3. (a) 30.5 oz (b) 6.3 oz
4. (a) 30.0 oz (b) 6.0 oz

9-23. If the auxiliary boiler water alkalinity is found to be 0.8 epm, how many ounces of TSP must be used to raise the alkalinity to 2.0 epm?

1. 22.5 oz
2. 20.0 oz
3. 18.0 oz
4. 16.5 oz

9-24. If after adding TSP you have a phosphate correction equaling 170 ppm, how many ounces of DSP will be required to raise the phosphate to 300 ppm?

1. 7.3 oz
2. 7.5 oz
3. 7.8 oz
4. 8.0 oz

● Questions 9-25 through 9-27 are to be judged True or False.

9-25. Treatment in accordance with the DSP dosage table will bring the alkalinity level to the upper limit of 400 ppm.

9-26. From the standpoint of feedwater consumption, it is better to secure and dump the boiler when the alkalinity level is 6 epm or when the phosphate level is 1200 ppm.

9-27. If the boiler water chloride level exceeds 30 epm, it is better to control it through surface blowdowns rather than by dumping, flushing, and refilling the boiler.

Learning Objective: Indicate factors that contribute to the correct and efficient operation of hydraulic systems and related components; also recognize some sources of trouble that may be encountered.

9-28. The overall efficiency of a hydraulic installation that drives auxiliary machines is determined by which of the following factors?

1. Size
2. Oil pressure
3. Speed and stroke
4. All of the above

9-29. Major repairs to hydraulic units should be accomplished by which of the following facilities?

1. A naval shipyard
2. A SIMA group
3. A tender
4. Each of the above

● Questions 9-30 and 9-31 are to be judged True or False.

9-30. A main step in troubleshooting an electrohydraulic system is to determine whether the faulty condition is in the hydraulic, mechanical, or electric part of the system.

9-31. You should never disassemble a hydraulic unit, unless you are certain the trouble is in it.

9-32. What is the recommended method for locating small internal leaks in hydraulic systems?

1. Use magnetic flux
2. Install pressure gages
3. Listen for identifying sounds
4. Visually inspect the disassembled parts

● Question 9-33 is to be judged True or False.

9-33. The most frequent symptom of trouble in a hydraulic system is indicated by unusual noise.

9-34. A popping or sputtering noise in a hydraulic system indicates which of the following conditions?

1. Oil leak in the pressure line
2. Air leak in the pressure line
3. Air leak in the suction line
4. Air pocket in the cylinder

9-35. Which of the following conditions should you suspect if a pounding or rattling noise occurs in a hydraulic system?

1. Overtight adjustment of parts
2. Defective spring-activated valve
3. Improperly adjusted relief valve
4. Overloaded system or high-speed operation

9-36. Foreign matter in the oil of a hydraulic transmission usually causes which of the following types of noises?

1. Rattling
2. Popping
3. Squealing
4. Grinding

9-37. When a squealing or squeaking noise occurs in a hydraulic system, it is usually caused by which of the following conditions?

1. Wiped bearings
2. Air pocket in the cylinder
3. Overtight packing around moving parts
4. Overloaded system during high-speed operation

9-38. What should an Engineman do if a faulty operation of a circuit breaker is discovered?

1. Repair the circuit breaker
2. Check for excessive binding in the electric motor
3. Replace any damaged equipment in the lines
4. Report the condition to the Electrician's Mate

9-39. If a hydraulic system is left idle for long periods of time, which of the following difficulties may be expected to develop?

1. Misalignment of linkage
2. Accumulation of sludge
3. External leakage
4. Internal leakage

9-40. Evidence of which of the following foreign substances in the oil of a hydraulic system calls for draining the oil, cleaning the system, and filling it with clean oil?

1. Water
2. Sludge
3. Acid
4. Each of the above

9-41. What is the purpose of securing a hydraulic system for 1 hour after filling it with flushing oil?

1. To permit the settling of foreign matter
2. To dissolve sludge
3. To permit the venting of air
4. To dissolve corrosive deposits

9-42. Which of the following actions is part of the procedure for cleaning a hydraulic system?

1. Allow the system to remain idle for 15 minutes after operating it with a light load for 4 minutes
2. Operate the system for an hour while it is filled with cleaning fluid
3. Operate the system at high pressure while it is filled with cleaning fluid
4. Dilute the old hydraulic oil with cleaning fluid and operate the system for 15 minutes, then allow the system to remain idle for about 5 minutes

9-43. You are replenishing the hydraulic system with oil, what should you use to strain the oil?

1. A cheese cloth
2. An aluminum filter
3. A 200-mesh wire screen
4. A 400-mesh wire screen

9-44. If you are filling a hydraulic system and notice water in the oil, what should you do?

1. Centrifuge the oil or reject it
2. Run the oil through a 200-mesh strainer
3. Heat the oil to permit the water to evaporate
4. Allow the oil to stand until the water sinks to the bottom

● Question 9-45 is to be judged True or False.

9-45. Opening the air valves to a hydraulic system will allow any air pockets formed in the unit to vent into the oil expansion box.

9-46. What type of material is used to form the shaft seal of most modern hydraulic pumps?

1. Rubber
2. Neoprene
3. Asbestos
4. Flax

9-47. What condition can cause the packing of a shaft stuffing box to wear out quickly?

1. Hard packing
2. Rough shaft
3. Shaft deflection
4. Excessive packing

9-48. What is the main purpose of packing a shaft packing gland uniformly and lightly?

1. To allow for cooling and lubrication
2. To prevent scoring of the shaft
3. Roth 1 and 2 above
4. To prevent binding of the shaft

9-49. Assume that a routine inspection reveals a leak in the line of a hydraulic system at a flanged joint. If the leak persists after the bolts have been tightened evenly, what will be the proper corrective procedure to follow next?

1. Replace the flanges
2. Install new packing
3. Inspect the fluid for contaminants
4. Install square-braided asbestos packing

9-50. How should you cut out an auxiliary line of a hydraulic system if you want the rest of the system to continue to operate?

1. Close the valves of the ram cylinder
2. Cut in a new pump
3. Cut out the three-way valve
4. Valve off the line from the connection to the main line

● Questions 9-51 and 9-52 are to be judged True or False.

9-51. The three-way valve in a hydraulic gear installation may be used to shift from the operating pump to a standby pump.

9-52. Replenishing lines installed to hydraulic systems of older ships are a source of leakage troubles because pressures are in excess of 300 psi.

9-53. The relief valves in a hydraulic system leak. What should you do to the valve seats?

1. Reface them
2. Replace them
3. Regrind them
4. Fit them with seat inserts

9-54. Which of the following steps should you take to correct an inoperative shuttle valve?

1. Replenish the oil supply
2. Secure the expansion tank
3. Adjust the valve to allow more liquid to flow through
4. Close the stop valves and remove the valve for repairs

● Questions 9-55 through 9-58 concern the hydraulic servovalve shown in textbook figures 9-4 and 9-5.

9-55. The feedback signal which sets in motion the fine control required to actuate the servovalve may be produced by which of the following means?

1. Electricity
2. Fluid pressure
3. Mechanical links
4. All of the above

9-56. What will the magnetic reed do when the input signal matches the feedback signal to the amplifier?

1. It starts to vibrate
2. It returns to neutral
3. It blocks the right nozzle
4. It blocks the left nozzle

9-57. When the left solenoid is energized, in what direction does the reed move and what action of the spool valve results?

1. The reed moves right and the spool valve moves left
2. The reed moves left and the spool valve moves right
3. Both the reed and the spool valve move to the left
4. Both the reed and the spool valve move to the right

9-58. The spool valve is returned to a central position by spring action when the fluid pressure is relieved through which of the following chambers?

1. A
2. B
3. C
4. D

Assignment 10

Auxiliary Machinery (continued)

Textbook Assignment: Engineman 1&C, NAVEDTRA 10543-E1, pages 7-22 through 8-21

Learning Objective: point out the operational, troubleshooting, and repairing techniques for the submerged tube and the flash-type distilling plants.

10-1. Which of the following ships have vapor compression distilling units?

1. Aircraft carriers
2. Submarines
3. Destroyers
4. Frigates

● Questions 10-2 through 10-21 refer to low-pressure submerged tube distilling plants.

10-2. Varied operating conditions are a primary cause of which of the following problems?

1. Changes in feed levels
2. Scaling of evaporator tubes
3. Improper liquid level in the first effect
4. Higher steam pressures

10-3. You need to adjust three controls in order to bring heat and fluid condition into balance. You should use which of the following techniques?

1. Adjust all three controls simultaneously
2. Adjust all three controls singly and quickly
3. Adjust each control singly and in increments
4. Adjust each control at lo-minute intervals

10-4. Which of the following factors is/are most likely to cause a decrease in the plant's efficiency?

1. Air leaks in the first tube nest
2. Low volume in the last-effect shell
3. Dirty circulating water strainer
4. All of the above

10-5. Steam orifices should be inspected how often?

1. Monthly
2. Biannually
3. Annually
4. With each overhaul

10-6. Water used to desuperheat live steam should be taken from what source?

1. The first-effect tube nest drain pump
2. The second-effect tube nest drain pump
3. The freshwater supply
4. The steam feed system

10-7. Fluctuations in the first-effect steam pressure and temperature cause similar fluctuations in which of the following parts of the plant?

1. The second effect only
2. The steam supply line only
3. The water levels only
4. The entire plant

10-8. Tubes in the first-effect tube nest should be cleaned whenever the mercury drops below which of the following levels?

1. 1 in.
2. 1 1/2 in.
3. 2 in.
4. 2 1/2 in.

10-9. When you can NOT feed water into the first effect, you should look for which of the following causes?

1. Scale deposits in the air ejector condenser
2. Scale deposits in the vapor feed heater
3. Obstructions in the feed line
4. All of the above

10-10. Once the plant is in operation, which of the following problems is most likely to cause priming?

1. A sudden rising of the water level
2. A water level that is too high
3. Both 1 and 2 above
4. A sudden drop in the water level

10-11. The vacuum gage readings are nearly identical for the first and second effects. What is the most likely cause?

1. Air leaks between the first and second effects
2. Equally low water levels in both effects
3. Equally high water levels in both effects
4. Obstructions in the flow between the first and second effects

10-12. You have an air leak and your watchstander has been operating the air ejectors improperly. These conditions can be expected to produce which of the following vacuum readings in the last effect shell?

1. 34 in. of mercury
2. 30 in. of mercury
3. 26 in. of mercury
4. 10 in. of mercury

10-13. When the plant is in operation, which of the following vacuum tests may be made on joints?

1. Air pressure
2. Candleflame
3. Soapsuds
4. Hydrostatic

10-14. A hydrostatic leak test on a nonremovable tube bundle is conducted at (a) what pressure, and (b) on what side of the unit?

1. (a) 50 psi, (b) the tube side
2. (a) 50 psi, (b) the shell side
3. (a) 30 psi, (b) the tube side
4. (a) 30 psi, (b) the shell side

● Use the following situation to answer questions 10-15 through 10-17 as True or False: A low vacuum reading indicates a problem with the air ejector.

10-15. If you believe the problem is low steam pressure, you should try to overcome the problem by removing and cleaning the nozzle.

10-16. Air ejector nozzles should be cleaned with a thin rattail file.

10-17. A damaged strainer or nozzle should be replaced with a new one.

10-18. The temperature of circulating water rises more than 20°F as it passes through the distiller condenser. What should you do first?

1. Clean the air ejectors
2. Inspect the condenser circulating water systems
3. Check for improper operating procedures
4. Reset the back pressure-regulating valve

10-19. Which of the following indicators suggests improper drainage of the' distiller condenser?

1. The flash chamber gage glass is flooded
2. The first-effect tube nest vacuum is several inches of mercury
3. The plant does not produce designed output when the orifice is 5 psig
4. All of the above

10-20. On older plants, brine density is adjusted by what control(s)?

1. The evaporator heat control valve
2. The hand-controlled valve located in the discharge line of the brine overboard pump
3. The wire control valve
4. The first-effect feed valve

10-21. A salinometer measures the degree of salinity in a sample of brine taken from what source?

1. The discharge side of the brine pump
2. The intake side of the brine pump
3. The first-effect feed valve
4. The second-effect feed valve

● Questions 10-22 through 10-29 refer to flash-type distilling plants.

10-22. What is the maximum design feedwater temperature?

1. 75°F
2. 85°F
3. 165°F
4. 175°F

10-23. During operation of the plant, a pressure reduction occurs in each stage to enable the plant to

1. function with a steady, even flow of feedwater throughout the plant
2. produce as much vapor in the fifth stage as in the first
3. control the feedwater temperature within the specified limits
4. produce an increased amount of vapor in each successive stage

10-24. Distillate leaving the cooler is pumped to storage tanks only if the salinity reading is NO greater than

1. 0.045 epm
2. 0.055 epm
3. 0.065 epm
4. 0.075 epm

10-25. The four thermometers mounted on the saltwater heater measure which of the following temperatures?

1. Feedwater inlet and outlet
2. Steam surrounding the tubes
3. Desuperheating temperature
4. All of the above

10-26. Cooling water from the air ejector precooler flows into which of the five heat exchangers mounted on the evaporator?

1. Second
2. Third
3. Fourth
4. Fifth

10-27. How many inches of mercury are required in stage 5 of the evaporator?

1. 24 in.
2. 26 in.
3. 28 in.
4. 30 in.

10-28. What is the purpose of the duplex strainer?

1. To clean steam going to the preheater air ejector
2. To remove solid matter from seawater
3. To remove impurities from freshwater
4. To remove noncondensables from the saltwater heater

10-29. The relief valve in the feedwater inlet is set to open at what pressure?

1. 71 psig
2. 73 psig
3. 75 psig
4. 77 psig

● Questions 10-30 through 10-34 concern the maintenance of a flash-type unit, and should be judged True or False.

10-30. Air leakage in the brine and distillate pumps will have NO effect on vacuum.

10-31. The saltwater heater requires more frequent cleaning than the distillate cooler.

10-32. The orifices in the feed boxes are more likely to be plugged by foreign matter than by scale.

10-33. A relief valve that is continually popping should be scheduled for routine maintenance as time permits.

10-34. Pneumatic-type reducing valves should be used only for low-pressure applications.

Learning Objective: Specify maintenance and adjustments required on relief and reducing valves, and recognize some of the troubles that may be encountered with each.

10-35. Which of the following procedures must always be followed after a relief valve is removed?

1. Reset the spring tension
2. Reduce the pressure
3. Grind the disk
4. Grind the seat

10-36. A pneumatic pressure-controlled reducing valve may be used on which of the following supply lines?

1. Galley steam
2. Fuel oil
3. Freshwater
4. Each of the above

10-37. Which of the following conditions can cause a spring-loaded reducing valve to function improperly?

1. Main or auxiliary valve fails to seat properly
2. Adjusting spring requires readjustment or replacement
3. Foreign matter is deposited on the working parts of the valve
4. Each of the above

10-38. Which of the following corrective actions to a spring-loaded reducing valve may require facing-off the valve stem end to obtain the proper clearance between the diaphragm and valve stem end?

1. Lapping-in the main valve
2. Replacing the valve diaphragm
3. Grinding-in the auxiliary valve
4. Adjusting the valve spring tension

● Question 10-39 is to be judged True or False.

10-39. The proper water seal level is maintained in the upper half of the dome on the pneumatic pressure-controlled reducing valve by steam condensation.

10-40. When a pneumatic pressure-controlled reducing valve is being installed or replaced, care must always be taken to replace which of the following seals?

1. The water seal in the upper half of the dome
2. The water seal in the lower half of the dome
3. The glycerine seal in the upper half of the dome
4. The glycerine seal in the lower half of the dome

10-41. Assume that, when repairing a pneumatic pressure-controlled reducing valve, you lose the water seal. Why must you replace the water seal before putting the valve back in service?

1. To prevent the glycerine from contacting the diaphragm
2. To prevent the steam from contacting the diaphragm
3. To allow the glycerine to come in contact with the diaphragm
4. To allow the steam to come in contact with the diaphragm

10-42. If the glycerine of a pneumatic pressure-controlled reducing valve must be replenished and NO glycerine is available, which of the following actions should you take?

1. Leave the lower seal empty for the time being
2. Use water for the lower seal until you can get glycerine
3. Use oil for the lower seal until you can get glycerine
4. Shut off the valve and tag it inoperable until you can get glycerine for the lower seal

10-43. The discharge pressure of a reducing valve increases above the desired amount. What is the most likely cause of this?

1. A broken spring
2. Failure of the diaphragm
3. A change in air temperature
4. Poor valve seating due to dirt or water

10-44. A check on a closed reducing valve which has failed to deliver steam shows that the dome pressure gage reads the same as the outlet pressure gage. What is the likely cause of this problem?

1. The diaphragm has failed
2. The valve stem is binding
3. The filling plug is leaking air
4. Temperature changes are causing the air to expand

10-45. In case of an oil spill, which of the following persons will be assigned the specific responsibility to direct the cleanup operation?

1. CNO
2. On-scene coordinator
3. Area coordinator
4. On-scene commander

● Question 10-46 is to be judged True or False.

10-46. In the Navy, only major Navy-related spills must be reported.

10-47. The person responsible for maintaining a detailed log of spill-related activities is the

1. CNO
2. area coordinator
3. on-scene coordinator
4. on-scene commander

10-48. The first corrective actions to be taken as soon as possible after a spill has been discovered are known as

1. discovery and notification
2. containment and countermeasures
3. recovery and disposal
4. documentation and cost recovery

10-49. What is the main reason for isolating and evacuating a spill area?

1. To protect life
2. To protect health
3. Either 1 or 2 above
4. To protect the environment

10-50. Booms are available in various heights and depths designed to meet their use requirements under various wind and sea conditions. What is the usual length of a boom?

1. 25 ft
2. 50 ft
3. 75 ft
4. 100 ft

10-51. Procedures to contain oil spills on land depend on all but which of the following factors?

1. Amount of oil
2. Type of oil
3. Source of oil
4. Type of soil

10-52. A spill of JP-4 is allowed to evaporate. This is an example of

1. fuel removal
2. fuel containment
3. fuel isolation
4. fuel evacuation

10-53. Which of the following methods of fuel removal may be allowed only if the oil can NOT be removed by other means?

1. Biodegradation
2. Burning
3. Dispersion
4. Evaporation

10-54. Physical-mechanical methods of oil removal include the use of skimmers. Which of the following types of skimmers is based on the Weir principle and is designed for use in congested harbor areas?

1. Small
2. Large
3. Suction base
4. Sorbent surface

10-55. Which of the following types of skimmers work best in calm, debris-free waters because of their high susceptibility to wave action and clogging?

1. Small
2. Medium
3. Large
4. Suction-based

10-56. The Mark I Spill Control Kit is best used with which of the following kinds of oil spills?

1. Protected open-water spills
2. Small ship-side spills
3. Congested harbor area spills
4. Large area spills

10-57. The use of which of the following agents is prohibited by Federal regulations?

1. Emulsifiers
2. Sinking agents
3. Gelling agents
4. Burning agents

● Question 10-58 is to be judged True or False.

10-58. Whenever possible, the oil collected from a spill should be burned.

10-59. Which of the following is the cause of the majority of oil spills?

1. Human error
2. Obsolete equipment
3. Leaky containers
4. All of the above

10-60. Regulations that require the Navy to control sewage discharge were promulgated by the

1. President of the United States
2. Secretary of Defense
3. Secretary of the Navy
4. Chief of Naval Operations

10-61. In what year was the decision made to install CHT systems aboard ships?

1. 1970
2. 1972
3. 1976
4. 1980

10-62. On large ships, the goal of the CHT system is to provide the capacity to hold shipboard sewage generated over what period of time?

1. 24 hr
2. 12 hr
3. 6 hr
4. 3 hr

10-63. All internal surfaces of CHT tanks must be coated in accordance with which of the following publications?

1. Naval Ships' Technical Manual, Ch 631 (9190)
2. Naval Ships' Technical Manual, Ch 503 (9470)
3. NAVFAC P-908
4. OPNAVINST 6240.3E

10-64. Comminutor and aeration systems are used with ships whose holding tanks' capacities are at least

1. 1000 gal
2. 2000 gal
3. 3000 gal
4. 4000 gal

10-65. A high level alarm sounds. What immediate action should you take to prevent flooding of the spaces?

1. Close isolation valves on the upper and the lower drains
2. Open the isolation valves on the upper and the lower drains
3. Close isolation valves on drains below the overboard discharge and divert the upper level drains overboard
4. Open isolation valves on drains below the overboard discharge and divert the upper level drains overboard

● Question 10-66 is to be judged True or False.

10-66. Exposure to continued or intermittent sounds can cause loss of hearing.

10-67. Loss of hearing sensitivity generally occurs in which of the following ranges?

1. 6,000 to 10,000 Hz
2. 4,000 to 6,000 Hz
3. 3,000 to 4,000 Hz
4. 500 to 3,000 Hz

10-68. What is the purpose of the hearing conservation program?

1. Identify noise sources
2. Reduce exposure of personnel to potentially hazardous noises
3. Test the hearing of noise-exposed personnel
4. Provide hearing-conservation devices

● Question 10-69 is to be judged True or False.

10-69. All personnel who are exposed to potentially hazardous noise may wear hearing protection devices at their own discretion.

Assignment 11

Engineering Casualty Control

Textbook Assignment: Engineman 1&C, NAVEDTRA 10543-E1, Pages 9-1 through 9-13

Learning Objective: Point out the purpose of engineering casualty control and indicate sources of specific information.

11-1. What is the primary objective of engineering casualty control?

1. To minimize personnel casualties
2. To operate engineering equipment at maximum economy
3. To maintain the efficiency of the engineering equipment
4. To minimize secondary damage to the engineering equipment

11-2. In battle, which of the following casualties would most affect the primary objective of engineering casualty control?

1. Injury to five people in the engineering department
2. Rupture of the primary firemain
3. Loss of the engineer officer
4. Bent compressed air piping

11-3. An indirect effect of engineering casualties suffered by a ship is the loss of

1. mobility
2. offensive power
3. defensive power
4. personnel morale and efficiency

11-4. What is/are the secondary objective(s) of casualty control?

1. To minimize personnel casualties
2. To minimize secondary damage to nonvital equipment
3. Both 1 and 2 above
4. To isolate machinery spaces

11-5. In which of the following publications can detailed information on casualty control be found?

1. In the Damage Control Book and the Engineering Casualty Control Manual
2. In the Ship's Organization Book and the Ship's Repair Party Manual
3. Both 1 and 2 above
4. In the manufacturer's instruction book and the 3-M Manual

Learning Objective: Recognize some factors influencing the effectiveness of engineering casualty control.

11-6. Which of the following actions should contribute towards an effective engineering casualty control program?

1. Constant training of personnel
2. Thorough maintenance of plant
3. Cross-connection of duplicate vital
4. Each of the above

11-7. Your training program in casualty control must include adequate and proper means for disseminating information. Failure to incorporate casualty control communication into your training program will result in which of the following conditions?

1. Failure of your casualty control organization to fulfill its primary objective
2. Possibility of more serious casualties than the original one
3. Both 1 and 2 above
4. Need for the establishment of a control station

11-8. Preventive maintenance involves continuous inspections of equipment to detect possible symptoms of malfunctions which may be indicated by which of the following symptoms?

1. Unusual noises
2. Unusual vibrations
3. Abnormal temperatures, pressures, and speeds
4. Each of the above

11-9. After showing a normal reading for a long time, a pressure gage on a pressure-governor-controlled pump suddenly shows a sharp rise in pressure. What is the Possible cause of the rise?

1. Disorder of the gage
2. Disorder of the governor
3. Internal mechanical failure
4. Each of the above

11-10. Which of the following factors may explain why a defective pump may lose its pumping capacity before any external evidence of failure is noticeable?

1. The designed safety margin of the Pump
2. Improper setting of the pump governor
3. Disorder of the safety devices
4. Disorder of the pump gages

11-11. A material failure is discovered in one of the fuel pumps. Which of the following is the proper correct actions you should take?

1. Inspect all similar pumps for the same defect
2. Repair or replace the damaged pump
3. Clean out the entire fueling system
4. Replace all similar pumps

11-12. How often should an oil sample be taken from all auxiliary machinery and tested for water contamination?

1. Daily
2. Weekly
3. Monthly
4. Quarterly

11-13. Lubricating oil which contains saltwater will damage all types of bearings. To which of the following bearings types is contaminated oil particularly harmful?

1. Pivoted shoe-type thrust bearings
2. Piston pin bearings
3. Roller bearings
4. Ball bearings

11-14. Simulated casualty exercises are often rendered ineffective because of which of the following reasons?

1. Inadequate use of dry runs
2. Inadequate advance preparation
3. Lack of Personnel with battle experience
4. Limited number of simulated casualties

Learning Objective: Recognize the methods and importance of preventing progressive casualties.

11-15. Continuous operation of equipment under casualty conditions is a responsibility of which of the following ship's officers?

1. Operation officer
2. Commanding officer
3. Engineering officer
4. Officer of the watch

11-16. What is the most important factor in efficient casualty control procedures?

1. Speed in restoring damaged units
2. Accuracy of corrective action
3. Status of personnel training
4. Speed in cross-connecting an intact system with a partially damaged system

11-17. During which of the following circumstances may an intact propulsion plant be cross-connected with a damaged plant?

1. When the auxiliary units become impaired
2. When casualties have become cumulative
3. When this procedure will not endanger the intact plant
4. All of the above

11-18. During damage control operation, the arresting secondary damage effects to engineering plant units is known by which of the following terms?

1. Limited corrective action
2. Emergency restoration
3. Complete repair
4. Split-plant operation

11-19. Which, if any, of the following casualty control phases is concerned primarily with complete repairs of the casualty?

1. Phase 1
2. Phase 2
3. Phase 3
4. None

11-20. Prevention of secondary damage effects to engineering plants is an objective considered to be a/an

1. limited corrective action
2. emergency restoration
3. complete repair
4. split-plant operation

11-21. What is the primary reason for maintaining a split-plant condition on a ship?

1. To simplify damage control procedures
2. To simplify normal maintenance procedures
3. To minimize the possibility of overall casualty to the engineering plant
4. To minimize mechanical fatigue in each separate plant

● Question 11-22 is to be judged True or False.

11-22. A ship's engineering plant which is split into two or more independent systems will NOT provide insurance against damage to the engineering plant.

11-23. If the ship's fuel oil system is in split-plant operation, bow does the after fuel oil service pump operate?

1. It takes suction from the after service tanks and discharge to the forward main engines
2. It takes suction from the after service tanks and discharged to the after main engines
3. It takes suction from the forward service tanks and discharge to the after main engines
4. It takes suction from the forward service tanks and discharge to the main forward main engines

11-24. Each ship's diesel-electric generator plant can operate independently and carry its own connected load. This type of setup is known as

1. segregation
2. duplication
3. split-plant
4. flexibility and adaptability

11-25. Which of the following is a component of a diesel-electric drive installation and is designed for split-plant operation only?

1. Cooling system
2. Main diesel engines
3. Propulsion generators
4. Starting air compressor

11-26. Which of the following methods for locking the main shaft of a diesel-electric drive ship can NOT be used while the ship is underway?

1. The energizing of the electrical propulsion circuits
2. The setting up of a jury rig to hold the main shaft stationary
3. The using of brakes to hold the main shaft stationary
4. The using of a jacking gear specifically designed for that purpose

11-27. Formulating engineering casualty procedures pertinent to a specific type of propulsion plant is the responsibility of which of the following personnel?

1. Type commander
2. Squadron commander
3. Engineer officer
4. Commanding officer

11-28. What is the first consideration to keep in mind in the event of casualty to propulsion machinery?

1. Immediate suspension of the operation of the damaged plant
2. Prevention of further damage to the plant and its auxiliaries
3. Speedy restoration of the damaged plant
4. Immediate isolation of cross-connected plants

Learning Objective: Identify procedures to be followed for specified engineroom casualties.

11-29. An engineroom casualty reduces the ability of the engineroom crew to answer bells. Who is the first person who should be notified?

1. Officer of the deck
2. Main propulsion assistant
3. Engineer officer
4. Commanding officer

● Question 11-30 is to be judged True or False.

11-30. The Engineering Casualty Control Manual contains detailed information on diesel engine casualty control procedures.

11-31. Assume the ship is underway and one of the propulsion engines shows symptoms of a broken injector tip. What is the first step you should take to correct the casualty?

1. Notify the OOD
2. Secure the engine
3. Cut out the injector
4. Notify the engineer officer

11-32. What is the first action that should be taken immediately after the lube oil pressure to the main engine has failed?

1. Secure the engine
2. Start the standby oil pump
3. Notify the engineer officer
4. Notify the officer of the deck

11-33. Water is discovered in an engine cylinder, which of the following methods should you use to determine its source?

1. Start the engine and visually check for leaks
2. Put a pressure test on the freshwater system
3. Check the cylinders by jacking over the engine with test cocks closed
4. Both 2 and 3 above

11-34. Checking the amount of fuel in the service tank is a part of the casualty control procedure in which of the following situations?

1. The speed governor has failed
2. The coupling is throwing oil
3. The fuel oil pressure has failed
4. The diesel fuel oil transfer pump is inoperative

11-35. What step or steps should you take after you discover the trouble in a diesel engine that is operating with its lube oil temperature above normal?

1. Report it to the POOW
2. Check the lube oil level
3. Reduce the engine load and speed
4. Request permission to secure the engine in order to make repairs

11-36. Your diesel oil day tank contains excessive water. Which of the following corrective actions must be taken prior to draining the water from all filters and strainers?

1. Drain all diesel oil lines to all engines
2. Notify the bridge of the casualty
3. Shift fuel oil suction
4. Both 2 and 3 above

● Question 11-37 is to be judged True or False.

11-37. The purifier may be used to supply diesel oil in the fuel oil system when a casualty occurs to the transfer pump.

11-38. Should the main lube oil pump fail, which of the following actions should you take?

1. Cross-connect the twin hydraulic coupling systems
2. Start the lube oil transfer pump or the standby pump and cut in on the line
3. Repair the lube oil pump as soon possible
4. All of the above

11-39. Assume the air brake to the propeller shaft is inoperative and the engine must be used for maneuvering. Which of the following is NOT a step in the procedure for continuing engine operation?

1. Increase the reducing valve air pressure
2. Use the throttle to control engine speed
3. Notify the OOD and the engineer officer
4. Secure the air brake system

11-40. Manual operation of the clutch dump valve permits continued operation of the engine after failure of which of the following parts?

1. Speed governor
2. Propeller shaft pneumatic brake
3. Coupling lube oil regulating valve
4. Thermostat control valve

11-41. Assume you have removed the inspection plate to a faulty heat exchanger to observe for leakage. After plugging the expansion tank vent, you should check for leaks by pressurizing which of the following parts of the ship's cooler?

1. The saltwater side from the ship's air supply system
2. The freshwater side from the ship's air supply system
3. The saltwater side from the ship's freshwater system
4. The freshwater side from the ship's freshwater system

11-42. During an emergency, which of the following steps should you take to allow an engine to continue operating with a leaking heat exchanger?

1. Request permission to speed up the affected engine and manually increase the freshwater cooling pressure
2. Request permission to slow down the affected engine and manually reduce the saltwater cooling pressure
3. Keep a constant watch for any abnormal temperatures or pressures and inform the engineer officer of the operating conditions
4. Roth 2 and 3 above

In answering questions 11-43 through 11-45, select the action in column B that should be taken to correct the casualty in column A.

A. Casualties	B. Actions
11-43. Propeller shaft pneumatic brake fails to operate	1. Renew the Oil
11-44. Diesel engine main shaft bearings over-heat due to grit or dirt	2. Regulate the valves manually
11-45. Hydraulic coupling is overheating	3. Check the electri-cal and pressure control switches to the air control valve
	4. Cross-connect the twin hydraulic coupling systems

11-46. What is the best emergency treatment if an overheated mainshaft bearing is found to be fitted improperly?

1. Renew the oil
2. Replace the oil rings
3. Provide an abundant supply of oil
4. Operate at low speeds until repairs can be made

11-47. Which of the following casualties should be investigated by means of a check on the oil discharge pressure?

1. Abnormal main shaft vibration
2. Abnormal noise in the reduction gear
3. Oil throwing by a coupling
4. Inoperative propeller shaft pneumatic brake

11-48. What is the first corrective action you should take if one of a ship's two propulsion shafts begins to vibrate excessively?

1. Slow both shafts
2. Slow the affected shaft
3. Investigate the fairwaters
4. Stop and secure the affected shaft

● Question 11-49 is to be judged True or False.

11-49. Personnel of the Engineman rating may be assigned duties on steam-driven ships to operate diesel-driven electric generating plants.

Learning Objective: Indicate sources of electrical power aboard ship, casualties that may occur, and methods of keeping vital equipment in operation.

11-50. What must you do if the ship's service generators fail during battle?

1. Ensure that the emergency system is rigged to supply power to vital auxiliaries
2. Ensure that the emergency system is automatically placed in operation
3. Ensure that the casualty power system is automatically placed in operation
4. Ensure that the casualty power system is rigged to supply power to vital auxiliaries

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In answering questions 11-51 through 11-53, select the action from column B that should be taken in the shipboard emergency described in column A to obtain power for vital equipment.

A. Emergencies	B. Actions
11-51. Failure of one ship's service generating plant	1. Shift vital equipment to an emergency feeder which receives power from the emergency switchboard
11-52. Failure of both normal and alternate power supply	2. Rig temporary circuits with the casualty power cables from any live switchboard
11-53. Failure of ship's service and emergency circuits	3. Transfer load to another ship's service generating plant
	4. Transfer the electrical load to an alternate feeder and source of ship's service power

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11-54. A ship's casualty power system provides sufficient power to

1. operate certain vital equipment only
2. permit the making of temporary repairs only
3. operate pumping equipment only
4. enable the ship to operate at near-normal efficiency

11-55. Which of the following components of the electrical system are placed above the waterline whenever practical?

1. Emergency generators
2. Ship's service and emergency generators
3. Emergency generators and switchboards
4. Ship's service and emergency switchboards

11-56. A ship's casualty power system is designed to provide enough emergency electric power for restoring the

1. services that are vital to the ship's survival
2. ship to near-normal operating efficiency
3. ship to normal operating efficiency
4. watertight boundaries and for making temporary repairs

11-57. You should be able to find your way quickly to sources of casualty power in the event of damage to the regular power system. Where can this source of power be located?

1. In a special housing switchboard
2. At the ship's central switchboard
3. At each emergency switchboard
4. At each ship's service switchboard and each emergency switchboard

11-58. What component is installed on power panels specifically for handling casualty power?

1. Bus bars
2. Transformers
3. Power terminals
4. Circuit breakers

11-59. The circuits that transmit a.c. casualty power to equipment designated to receive it consist chiefly of which of the following types of cable?

1. Portable 3-conductor
2. Vertical runs of insulated
3. Permanently installed armored
4. Horizontal runs of 2-conductor

11-60. On larger ships, the a.c. casualty power system generally consists of

1. one horizontal run, located inside the deck house
2. two horizontal runs, located on the second deck
3. two horizontal runs, located inside the deck house
4. one horizontal run, located on the second deck

11-61. Each riser terminal installed in a casualty power circuit provides a connection point for

1. two, 3-lead portable cables
2. two, 4-lead portable cables
3. three, 3-lead portable cables
4. three, 4-lead portable cables

11-62. The riser terminals of a casualty power system can be distinguished from the bulkhead terminals by which of the following characteristics?

1. The horizontal runs of the portable cable that connect the riser terminals to the other riser terminals
2. The horizontal runs of the portable cable that connect the bulkheads to the other bulkhead terminals
3. The vertical runs of the permanently installed armored cable that connect the riser terminals to the other riser terminals
4. The vertical runs of the permanently installed armored cable that connect the bulkhead terminals to the other bulkhead terminals

11-63. Phase identification of cable conductors is by color and by servings of cotton cord. Which of the following markings identifies a phase "B" cable?

1. White and two servings
2. Grey and three servings
3. Red and three servings
4. Black and one serving

11-64. You are connecting the leads in an a.c. casualty power system. Which of the following is always the safest procedure?

1. Connect the leads to a power panel while normal power is being supplied to it
2. Connect a black lead to a C terminal first
3. Connect the leads by working from the load to the power supply
4. Connect the two-serving lead to an A terminal first

11-65. All but which of the following are power sources for the electric-driven fire pumps aboard ship?

1. Ship's service generators
2. Diesel-driven emergency generators
3. Casualty power system
4. Transformers of the emergency lighting system

● Question 11-66 is to be judged True or False.

11-66. To supply an immediate source of lighting, in case of complete failure of the ship's service and emergency lighting systems, automatic bus transfers are installed at vital stations.

11-67. Maintenance of the hand battle lanterns in an engineering space and the making of them available for use at all times are responsibilities of which of the following personnel?

1. Electrician's Mate
2. PO in charge of the space
3. Electrician's Mate and PO in charge of the space, respectively
4. PO in charge of the space and Electrician's Mate, respectively

11-68. What is the maximum number of electrical power sources available to shipboard power panels?

1. One
2. Two
3. Three
4. Four

11-69. Where are the emergency portable, triple outlet extension cables stowed?

1. On bulkhead brackets
2. On overhead brackets
3. On bulkhead shelving
4. In damage control lockers